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THE NOVEMBER SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1931

MAN AS A PRIMATE

By Dr. ADOLPH H. SCHULTZ

LABORATORY OF PHYSICAL ANTHROPOLOGY, JOHNS HOPKINS UNIVERSITY

Introduction

In the classification of mammals the lemurs, monkeys, apes and man are placed in one order, called the primates. This natural group is composed of two rather sharply separated suborders, the prosimians (Prosimiae or Lemuroidea) and the simians (Simiae or Anthropoidea). The former suborder can be divided into a number of families and genera, such as the aye-aye, tarsier, loris, potto, bush-baby, endrina and the various types of lemurs, all of which have become specialized in more or less divergent directions, even though retaining in common many primitive features. The second and more highly developed suborder constitutes a comparatively uniform mammalian group. Since man must unquestionably be assigned to this second division of primates, the suborder of prosimians need not be further discussed in this paper.

According to Elliot,[1] who has written the most comprehensive taxonomic review of the primates, 57 genera and 593 species of recent primates can be distinguished. In this system man occupies but one species and genus. In other words, man represents only one of the nearly six hundred terminal twigs on the family tree of primates, and these twigs spread from fifty-seven branches of which only one is labelled "genus *Homo*." These six hundred different living primates are the present results of nature's lavish experimentation with one common ancestral stock. In their totality they cover a wide range of variations. This range has become broken up into distinct groups by the extinction of many intermediate forms. The irrefutable reasons for placing man within this range of primate variations are based upon the abundant findings of comparative anatomy, paleontology, embryology, physiology, etc. These findings have conclusively demonstrated that the fundamental similarities between man and at least some of the other primates far outweigh the dissimilarities, and that the latter are frequently no greater, or even much smaller, than the differences existing between other forms of primates.

This is not the place in which to review systematically the enormous bulk of old and recent anatomical evidence which forces us to regard ourselves as near cousins of the apes. This paper is almost entirely restricted to a discussion of some less widely known and mostly quite recent comparative studies on certain features appertaining chiefly to the outer body of primates and to their body proportions. These are the conditions responsible for any "family resemblance" in outer appearance between man and the apes. Only by studying

[1] D. G. Elliot, "A Review of the Primates" (3 vols.); Monograph I, Amer. Mus. of Nat. Hist., New York, 1913.

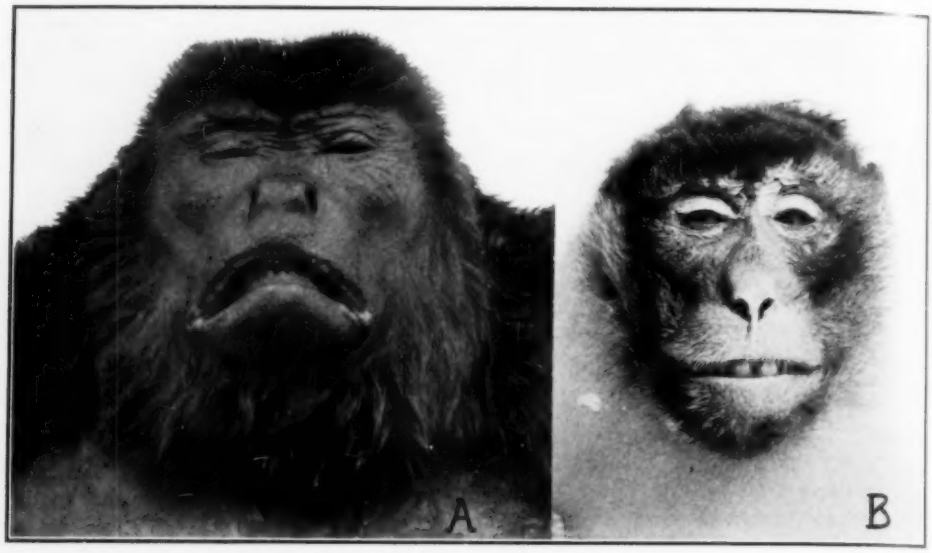

FIG. 1. FRONT VIEWS OF HEADS

A = ADULT MALE HOWLER MONKEY FROM CENTRAL AMERICA; *B* = ADULT MALE PHILIPPINE MACAQUE, SHOWING THE DIFFERENCE IN THE OUTER NOSE.

all the different groups of the Simiae does it become possible to recognize that there exist definite evolutionary trends, which have shaped the bodies of monkeys and man by advancing them in differing degrees along these regular paths, and that in regard to some bodily parts man represents the extreme of the respective trends, whereas in regard to many other parts, one or several of the apes have progressed beyond the stage reached by man. In addition there exists a great variety of detailed trends which clearly deviated here and there from the general evolutionary direction in response to special requirements for one-sided adaptations. By tracing the general trends through all the simian genera the conclusion is inevitably forced upon the investigator that the present form of the human body is merely the best that could so far be accomplished with the inheritance from our precursors, who were adapted to quite different conditions.

CLASSIFICATION

For a proper appreciation of man's position within the suborder of Simiae it is necessary to mention briefly at least a few of the reasons for subdividing this group according to definite distinguishing characters. The first and most fundamental division coincides with the geographical distribution of the suborder. All the aboriginal primates of Central and South America constitute the series Platyrrhinae which differs in many respects from the simians of Africa and Asia which form the series Catarrhinae. The most readily seen difference between these series consists in the formation of the nose. In the platyrrhines (="broad-nosed" monkeys) the nostrils open sidewise and are always separated by a broad septum, whereas in the catarrhines (="narrow-nosed" primates) the nostrils point forward and have moved so close together that only a narrow septum remains. This is shown by the two examples in

Fig. 1 (see also Fig. 7). There have been found many additional constant differences between American monkeys and the simians of the Old World. Thus, the former possess no outer bony tube leading to the ear drum, whereas in the latter such a tube is formed during growth after birth. Platyrrhines have always three premolar teeth on each side of each jaw, but catarrhines have only two of these teeth. According to these and all other distinguishing features man belongs in the series of Old World primates.

It is of great interest that, in spite of a comparatively uniform environment, the monkey population of tropical America has evolved along a great variety of diverging lines. Two families are recognized: The small and generally primitive marmosets and tamarins (Callithrichidae or Hapalidae) and the larger squirrel monkeys, howler monkeys, spider monkeys, capuchins, etc., known collectively as Cebidae. The former family possesses only two molar teeth on each side of each jaw, whereas in the latter family there are three of these teeth. The elimination of the last molar in the Callitrichidae is undoubtedly a late evolutionary specialization and one which seems to become repeated in spider monkeys, in which the third molars have been found to be congenitally lacking in 15 per cent. of the cases (Fig. 2). Incidentally, a similar evolutionary trend prevails among the higher races of man, in whom the dental arch tends to become shortened at exactly the same place, *i.e.*, by the gradual elimination of the last molar tooth. The Callithrichidae are the only simians which regularly give birth to two or occasionally even three young at a time.

As examples of the marked differences existing within the family Cebidae one may mention the heavy-chested and dull howler monkey which climbs with slow deliberation on top of the branches and the most highly developed of all platyrrhines, the spider monkey, which swings with easy rapidity by its slender elongated arms underneath branches, or runs occasionally on top of a broad limb on all fours, if not on its lower limbs alone.

The catarrhine simians are most properly divided into four distinct families. The least highly developed of these is the family Lasiopygidae (or Cercopithecidae) which includes all the great variety of African and Asiatic monkeys, such as the macaques, baboons, mangabeys, guenons, langurs, guerezas, etc. One of the most readily seen differences between these monkeys of the Old World and those of America exists in the region overlying the ischial tuber-

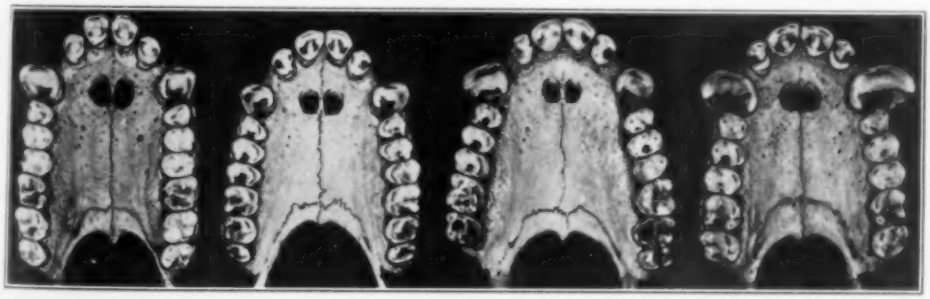

FIG. 2. UPPER JAWS OF ADULT SPIDER MONKEYS (*Ateles geoffroyi*, EASTERN NICARAGUA)

FROM LEFT TO RIGHT; THIRD MOLAR: OF USUAL LARGE SIZE; REDUCED IN SIZE, NUMBER OF TUBERCLES AND OF ROOTS; CONGENITALLY LACKING ON ONE SIDE; LACKING ON BOTH SIDES.

FIG. 3. FRONT VIEW OF AN ADULT MALE ORANG-UTAN, WEIGHING 170 LBS. PHOTOGRAPHED IMMEDIATELY AFTER DEATH (No. 212, HOPKINS COLLECTION).

osities of the pelvis. In the latter monkeys the skin of this region is as hairy as the rest of the body surface, whereas in the former there are always two large horny zones, the so-called ischial callosities. All these catarrhine monkeys are chiefly quadrupedal forms, with the spine horizontally posed in walking. They are excellently adapted to an arboreal life, only the baboons and a few species of macaques leading a largely terrestrial existence.

The second family, composed of the gibbons and the siamang (Hylobatidae), represents in many respects a transitional stage between the first and third groups of catarrhine primates. These small apes, which apparently have retained many features characteristic of the ancestral stock of all higher primates, have become specialized for the most extreme form of brachiation, *i.e.*, for swinging by their long arms and this with an amazing rapidity and dexterity. No other primate, not even the spider monkey or the orang-utan, is as expert an arm-swinger as is the gibbon. The Hylobatidae, like the lower catar-

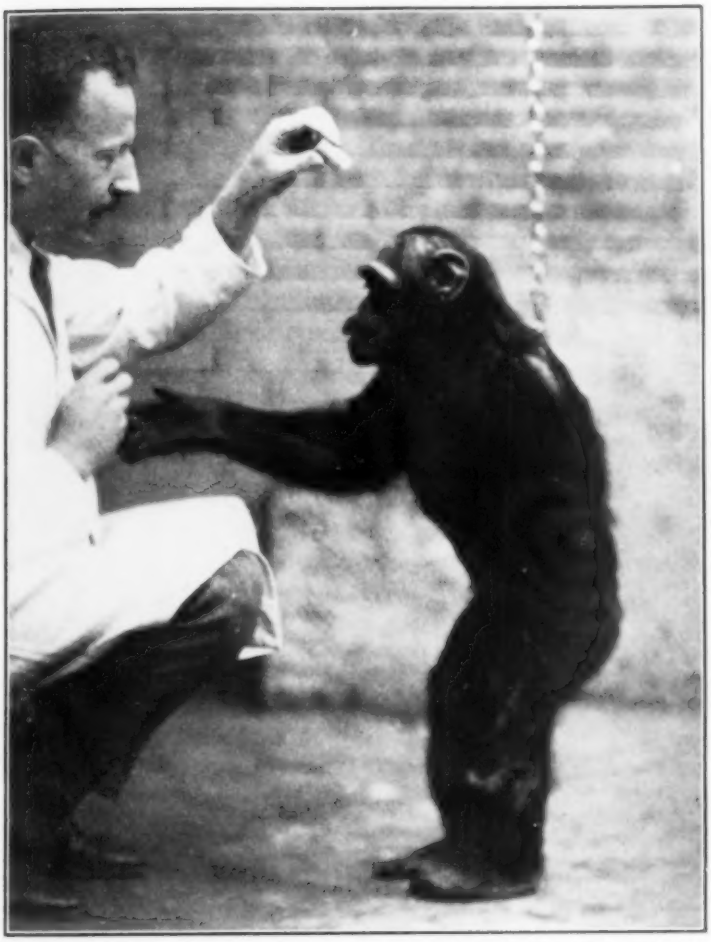

FIG. 4. THE FEMALE CHIMPANZEE OF THE ANATOMY DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY, STANDING UPRIGHT.

rhines, possess ischial callosities, but there exist indications of a gradual process of elimination of these structures among the higher primates. In the lower monkeys callosities appear in early fetal life sooner than the hair; in gibbons they replace the primary coat of hair at the time of birth; and in the siamang they do not develop until during infantile life. In the large anthropoid apes, finally, small ischial callosities are still present in occasional specimens, particularly among some species of chimpanzee.[2]

The third family of catarrhines comprises the three large apes: orang-utan, chimpanzee and gorilla. These are known collectively as Pongidae (or Anthropomorphae) and are sometimes combined with the gibbons as a single family (Simiidae). The Asiatic orang-utan is better adapted to an arboreal life than his two African cousins, of which the gorilla has become mostly terrestrial, at least in adult life. Male

[2] A. H. Schultz, "Studies on the Growth of Gorilla and of other Higher Primates," *Memoirs of the Carnegie Museum*, XI, 1927.

FIG. 5. THE MALE (FOREGROUND) AND THE FEMALE CHIMPANZEE OF THE ANATOMY DEPARTMENT OF THE JOHNS HOPKINS UNIVERSITY.
NOTE POSITION OF KNUCKLES IN THE MALE.

orang-utans often develop large cheek callosities (Fig. 3) which occur also in one of the baboons (Drill). They are furthermore characterized by an extensive throat pouch which far exceeds that of the siamang. These are merely two examples in support of the general statement that evolution frequently experiments with the modification of a local structure in a similar manner and simultaneously in several not closely related primates. Another example has already been quoted, namely the tendency to eliminate the last molar teeth in marmosets, spider monkey, and man. Some of the clearest examples consist in the elimination of the thumb in the American spider monkey and again in the African guereza, and in the tendency to reduce the length and number of segments of the tail in a variety of widely separated primates.

The two closely related African anthropoids can walk for short distances in a nearly upright position, but rarely, if ever, are their legs completely straightened in the knee and hip joints (Fig. 4). When walking in their usual

quadrupedal fashion these apes (and the orang-utan) hold their fingers bent and rest the weight on the knuckles, as is shown in Fig. 5. In response to this habit the middle segments of the fingers have developed horny layers, which curiously enough are already indicated in the fetus. The chimpanzee swings by its arms more frequently and much more rapidly than does the gorilla.

The fourth and last family (Hominidae) of catarrhine primates has for its single representative man, who has become the only cosmopolitan primate, finding sustenance in all climates. This is one of the reasons for regarding man as the most successful evolutionary experiment among all primates, even though others have become equally well adapted to their—strictly limited—environments. Man's unique specializations consist chiefly in the high development of his central nervous system and in the complete acquisition of the erect posture, which liberated his arms from the function of locomotion and enabled his hands to shape and use tools. Practically all differences between man and the apes can be understood as direct consequences of the two just mentioned specializations.

After these introductory notes some selected data will be presented with which to answer the following closely connected questions: Why must the gibbons and anthropoid apes be regarded as man's nearest relations? What are some of the general evolutionary trends which have produced so many similarities between man and the other most highly developed catarrhine primates? Are the gaps separating man from recent anthropoid apes comparatively large or small when measured by the scale of differences existing between the other primates?

Body Size

In regard to body size adult primates vary within wide limits. Some fully grown marmosets weigh only 9 ounces but some male gorillas more than 400 pounds. As shown by the data for the height of the trunk (from suprasternal notch to pubic symphysis) in Tables I and II, the lowly Callithrichidae, with the trunk height measuring as little as 110 mm, are the smallest simians. The Cebidae range in this dimension up to 290 mm in the highest form, the spider monkey. The lower catarrhines are considerably larger than the great majority of platyrrhine monkeys, reaching their maximum in males of certain baboons and of some langurs. Gibbons have remained comparatively small, rarely exceeding 16 pounds in weight, but the more highly specialized siamang can attain a weight of 28 pounds. Male orang-utans and many chimpanzees equal man in trunk height as well as in body weight, and the gorilla surpasses man in these respects to a very marked degree. There can be no doubt that among primates there prevails a general tendency to increase the size of the body with advance in evolutionary development. The anthropoid apes are the only primates as large as, or even larger than, man.

It may be mentioned here that sex differences in size are not uniform among the primates. In the majority, including man, the males are somewhat larger than the females, but in some types, such as the gorilla and many baboons, the males surpass the females in size enormously, whereas in gibbons, for instance, there exists practically no such difference. In spider monkeys, finally, the average size of males is actually somewhat smaller than that of females.

Tail

The relatively longest tail among all primates belongs to the American spider monkey. In one such monkey of the author's collection the outer tail measures 847 mm and the spine without

the tail only 374 mm. This record tail, therefore, amounts to 226 per cent. of the length of the precaudal spine. The same proportion varies usually between 100 and 200 among American primates, but in the uakari of Brazil this percentage has become reduced to only about 50, this being the only New World primate with a rather short tail. Among catarrhine monkeys the length of the tail has never been found to exceed 175 per cent. of the length of the precaudal spine, and in many forms this index barely reaches 100. In contrast to the platyrrhines, the Asiatic and African monkeys include a considerable number of species with very short or even practically absent tails. With what apparent ease and comparative rapidity the tail can become reduced is indicated by the following data: In an adult Philippine macaque the tail amounts to 135 per cent. of the length of the precaudal spine, but in another species of the same genus, the brown macaque, this percentage has decreased to only 9, and in a specimen of the closely allied Barbary ape to even less than 1! In the latter the fleshy button, representing the last remnant of an outer tail, no longer contains any vertebrae or striated muscles. In the genus of Celebes macaques the tails of several species have become almost as rudimentary as in the Barbary ape.

The tail is most highly developed in the platyrrhine monkeys, among which it can attain a tremendous length and include as many as 34 vertebrae. In a variety of forms the tail has become prehensile and for some distance along its ventral side it bears cutaneous ridges, similar to those on palm and sole. Such tails have assumed the function of a fifth hand, greatly facilitating climbing and enabling the animal actually to hang by its tail. Only one platyrrhine manifests a tendency to reduce its tail.

Among catarrhine monkeys the tail never attained as high a degree of development as in many platyrrhines. It can reach a very considerable length in guenons, guerezas, langurs, etc., but it is never prehensile and serves merely as a balancing rod. In a great variety of catarrhine monkeys the tail has become so much shortened that it must be practically useless; and in several species the tail has almost entirely disappeared from the surface. The number of caudal vertebrae in the latter has become reduced to only 3 to 6 (*e.g.*, Barbary ape and some Celebes macaques).

The gibbons, anthropoid apes and man have in common the complete absence of an outer tail, except in embryonic stages of growth. The number of tail vertebrae varies among these "tailless" primates between 1 and 6. According to the most extensive and recent data this number averages in man 4.2; in chimpanzee 3.3; in gorilla 3.1; in orang-utan 2.8; and in the gibbons 2.7. Man, therefore, has lost his tail less completely than the other higher primates.

Hair

Man's comparative lack of hair is commonly regarded as a unique condition and as being due to special causes, such as domestication or some form of selection. Recent studies[3] on the density of hair, however, have produced sufficient data to prove that a relative loss of hair has occurred in other higher primates, besides man, and that the human "hairlessness" is largely a matter of degree. Man is the least hairy primate, but in this respect there exist much smaller differences between man and some anthropoid apes than between the latter and the majority of the lower monkeys.

The number of hairs per square centimeter of scalp averages 312 in adult

[3] A. H. Schultz, "The Density of Hair in Primates," *Human Biology*, III, 1931.

man and can exceed 400 in an occasional white. The corresponding average for five adult anthropoid apes is 282. Catarrhine monkeys have on an average 910 hairs per sq. cm of scalp, some species having as many as 2,000. Among platyrrhines this figure can rise even to above 4,000 and the average obtained is 1,852. The approximate total number of scalp hairs is considerably higher in man than in any of the ten orang-utans and chimpanzees studied.

The number of hairs on a sq. cm of skin from the back averages 1,737 in American monkeys, 866 in monkeys of the Old World, 276 in the anthropoid apes, and practically 0 in man. Some platyrrhines have as many as 3,000 hairs and some of the lower catarrhines more than 2,000, whereas in an adult chimpanzee this figure is as low as 48 and in an adult gorilla as low as 109. The total number of hairs on the back is about 100,900 in an adult chimpanzee, but over 1,000,000 in, for instance, an adult guenon monkey. The difference between the nearly complete hairlessness of the human back and the density and total amount of hair on the large back of an anthropoid ape is very much smaller than the difference in these conditions between some anthropoid apes and many of the lower monkeys.

In all monkeys and apes the chest is considerably less hairy than the back. On a square centimeter of skin the chest supports on an average 610 hairs in platyrrhines (over 1,000 in some species), 172 hairs in lower catarrhines (400 in some species), 90 hairs in anthropoid apes (only 21 in an adult chimpanzee and even only 3 to 6 in adult male gorillas), and about 1 hair in man (9 or more in some individuals). The density of hair, therefore, can be greater on the chest of man than on the chest of gorilla. The ranges of variations in the approximate total numbers of chest hairs overlap in man and anthropoid apes.

FIG. 6. SIDE VIEW OF THE HEAD OF AN ADULT FEMALE PROBOSCIS MONKEY (NO. 68, HOPKINS COLLECTION).

All these observations indicate very decisively that the extensive loss of hair in man is merely the most extreme manifestation of a general evolutionary trend to reduce the hairy coat of the largest primates.

Nose

It is a wide-spread popular belief that man differs from monkeys not only in the absence of a tail and the scarcity of hair but also, for instance, in regard to his prominent nose. One glance at the nose of the Bornean proboscis monkey in Fig. 6 should dispel such an idea. This nose of record size represents a specialized new development; it is abundantly vascularized and supported by enormously increased wing portions of the nasal cartilages. The prominent nose of orthognathous human races originated chiefly in an indirect manner through the recession of the alveolary process underneath the nose. In some prognathous races, such as the Hottentots, the nose is hardly more

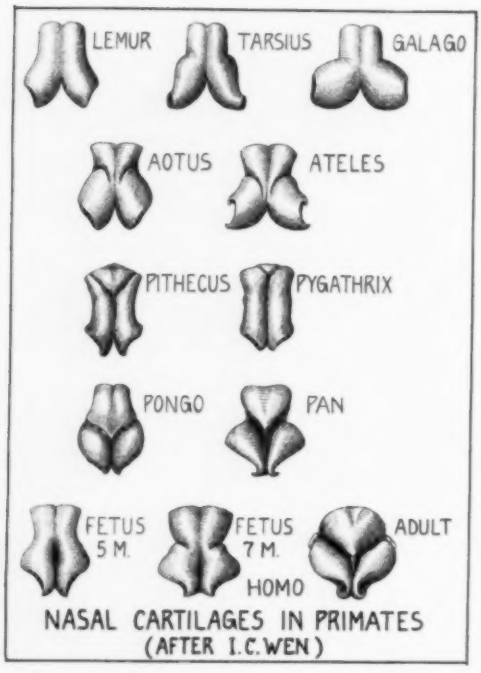

FIG. 7. FRONT VIEWS OF NASAL CARTILAGES IN SOME PRIMATES (AFTER I. C. WEN).

prominent than in some gorillas and at least one species of gibbon.

The shape of the outer nose is to a great extent determined by the size and arrangement of the cartilages within the nose, which extend from the nasal bones down to the nostrils. Fig. 7 illustrates some of the interesting results of a recent extensive investigation[4] of these structures. The top row shows the primitive condition of the nasal cartilages as still existing in prosimians. The two cartilaginous tubes are not yet divided into roof and wing portions. In platyrrhine monkeys such a separation appears for the first time, but is never complete, as shown by two representatives in the second row. A complete division of the primitive tubes into roof and wing cartilages is found only in catarrhine primates (third to fifth row in Fig. 7). Among the latter the conditions in adult man resemble those in orang-utan (Pongo) and chimpanzee (Pan) much more closely than those of the lower forms, as exemplified by Pithecus and Pygathrix. It is readily seen that these cartilages, which are little influenced by any specialized functions, correspond closely to the general classification of primates, as based upon the conditions in so many other structures.

The individual development of the nasal cartilages is most instructive, because it repeats faithfully the evolutionary changes which in all probability have taken place. In man, for instance, there are, during the first half of fetal life, only two undivided tubes, such as persist in a lemur throughout life. Soon afterwards a cleft appears on the lateral borders, exactly as in an adult platyrrhine (*e.g.*, *Aotus*). Not until shortly before birth are the cartilages of man completely divided; whereas in lower catarrhines this separation becomes complete even only after birth. From these findings alone it could be concluded that early in individual development the nasal cartilages of all primates must be closely alike, and that the various degrees of differentiation appear only in the course of growth, just as they have developed in the slow course of evolution. This constitutes merely one of innumerable examples supporting the so-called recapitulation theory, which claims that during the development of an individual there occur many inherited and passing reappearances of conditions having existed in the ancestors of the species at some (usually longer) period of their growth.

Ear

The outer ears of primates are surprisingly uniform in regard to many

[4] I. C. Wen, "Ontogeny and Phylogeny of the Nasal Cartilages in Primates," *Contribut. to Embryology*, No. 130, Carnegie Instit. Wash., 1930.

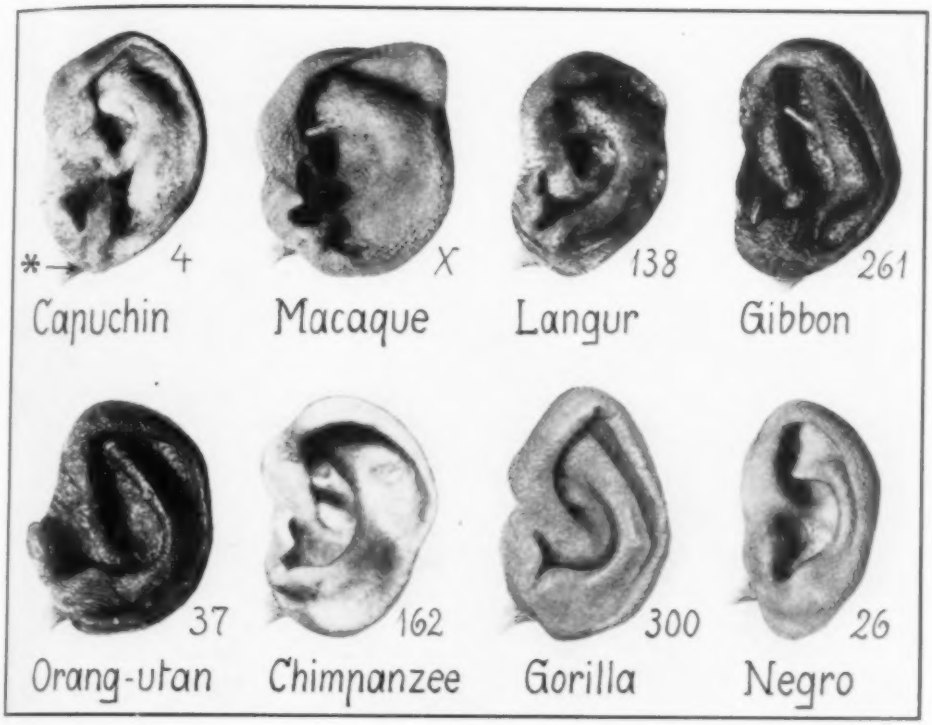

FIG. 8. THE EARS OF SOME PRIMATES (NUMBERS REFER TO CATALOGUE OF HOPKINS COLLECTION)

ALL THE HAIR HAS BEEN REMOVED. * = PLACE OF ATTACHMENT OF EAR TO CHEEK.

features, particularly those appertaining to the portion of the ear by which it is attached to the head. The unattached portion of the ear differs most in the various groups. In macaques, baboons and several other catarrhine monkeys this portion is comparatively flat and drawn into a point (Fig. 8). Among higher primates a strong tendency exists for the free edge of the ear (helix) to become rolled in. This is most pronounced in gibbons, in many orang-utans and gorillas, and in some human races. A true and large ear lobule, free of cartilage, is found only in the majority of human beings and in a considerable percentage of chimpanzees and gorillas. Among all primates the size of the ear has become most reduced in the orang-utan; in a very large male it measures in height only 39 mm. In chimpanzees, on the other hand, the ear is usually of a very conspicuous size, measuring in height 80 mm in one adult female in the Hopkins collection. Gorilla and man possess ears of about the same size (50 to 60 mm) which is intermediate between the two above mentioned extremes.

From these notes and the examples in Fig. 8, it is evident that the human ear resembles most closely that of the gorilla, the differences between the two being insignificant when compared with the differences between the lower and the higher primates.

Relative Size of Head

It is a well-known fact that man has by far the largest brain of all primates.

TABLE I

SOME BODY PROPORTIONS IN PRIMATES. THE FIRST 11 SPECIMENS REPRESENT 11 DIFFERENT GENERA OF THE SERIES PLATYRRHINAE (1 TO 3 = FAMILY CALLITHRICHIDAE, 4 TO 11 = FAMILY CEBIDAE). THE FOLLOWING 10 SPECIMENS HAVE BEEN SELECTED FROM 10 DIFFERENT GENERA OF THE LOWEST CATARRHINE FAMILY, LASIOPYGIDAE. THE FAMILY HYLOBATIDAE IS REPRESENTED BY FOUR SPECIES OF GIBBONS AND BY ONE SIAMANG. THE FOUR SPECIMENS MARKED BY AN ASTERISK ARE NOT QUITE FULLY GROWN, ALL THE OTHERS ARE ADULT

Species	Trunk height (mm)	Chest circumfer. / Trunk h.	Chest br. / Chest depth	Arm length / Trunk h.	Leg length / Trunk h.	Arm length / Leg length	Hand br. / Hand l.	Aver. head diameter / Trunk h.
Bald-headed tamarin ♂	110	90.0	95.9	111.7	110.0	101.6	29.8	26.6
True marmoset ♂	124	100.0	94.6	98.4	94.8	103.8	37.8	24.7
Marmoset ♂	159	110.0	93.2	100.2	99.7	100.6	34.8	23.3
Saki ♂	151	94.1	97.5	118.5	115.2	102.8	34.0	29.1
Uakari ♀	236	84.3	98.4	134.7	119.8	112.3	28.7	23.2
Squirrel monkey ♂	205	84.9	96.0	95.6	92.2	103.6	34.6	22.3
Night monkey ♂	191	101.0	92.9	103.3	100.5	102.8	31.4	22.5
Howler ♂	270	144.3	106.6	146.2	117.0	125.0	33.0	26.2
Capuchin ♂	268	106.7	105.0	119.3	115.5	103.2	32.6	24.1
Woolly monkey ♂	265	110.5	103.2	156.1	126.7	123.1	33.0	25.7
Spider monkey ♂	290	120.0	109.4	184.4	135.0	136.4	25.2	24.1
Baboon ♂	412	123.2	86.5	134.4	117.0	114.8	37.8	23.2
Celebes macaque ♂	298	130.4	74.4	145.5	129.5	112.3	33.9	25.2
Tailless macaque ♂	414	118.0	84.6	111.8	100.0	111.8	33.1	21.0
Macaque ♂	346	109.5	87.2	114.0	100.8	113.0	35.6	23.4
Mangabey ♂	296	117.1	78.8	127.7	120.5	105.8	37.2	24.4
Guenon ♂	352	98.9	82.5	100.7	96.5	104.3	34.4	20.8
Red guenon ♀	316	98.7	82.4	107.8	101.8	105.8	31.7	22.2
Langur ♂	357	94.7	90.5	108.0	97.8	110.5	28.8	17.5
Proboscis monkey ♀	353	97.8	103.0	139.5	113.5	122.8	28.6	18.9
Guereza ♀	417	82.7	96.0	103.8	96.9	107.1	31.9	16.5
White-handed gibbon ♂	254	149.5	117.4	251.0	152.7	164.3	20.0	25.6
Borneo gibbon ♀	260	151.5	123.5	239.6	148.3	161.3	25.0	24.7
Wau-Wau gibbon ♂	289	154.6	112.3	225.5	143.8	156.7	31.1	25.2
Sumatra gibbon ♀*	200	148.0	115.5	232.5	146.5	158.6	24.1	33.3
Siamang ♂*	248	160.0	120.5	234.1	131.4	178.1	29.4	29.4
Orang-utan ♀	399	156.8	116.4	204.6	128.6	159.1	30.6	33.3
Orang-utan ♀	440	159.7	120.5	191.7	107.3	178.5	26.3	27.3
Orang-utan ♂	508	190.0	130.0	197.3	116.2	169.5	35.0	25.1
Orang-utan ♂	498	217.8	140.9	204.6	120.8	169.2	37.8	27.2
Chimpanzee ♀	425	155.0	115.1	183.2	136.7	134.0	34.7	26.2
Chimpanzee ♀	478	185.3	124.8	178.3	128.8	138.4	32.2	25.1
Chimpanzee ♂*	464	165.4	133.3	165.7	119.0	139.1	36.5	26.7
Chimpanzee ♂*	463	180.0	122.7	166.6	128.7	129.5	35.9	28.5
Mountain gorilla ♂	687	216.9	144.6	159.6	115.6	137.8	58.1	22.9
Mountain gorilla ♂	723	196.5	146.8	147.8	109.2	135.2	59.0	21.5
Negro ♂	486	163.0	116.8	173.9	191.8	90.7	40.6	31.1
Hawaiian ♂	539	162.6	124.6	133.4	150.7	88.6	40.4	29.1
Chinese ♂	478	158.9	138.2	145.7	165.3	88.1	40.5	33.0
White ♂	494	167.2	115.8	143.3	160.8	89.2	44.9	32.8

In relation to the size of the body, however, many of the smaller monkeys possess a comparatively heavier brain than man.

The relative size of the brain part of the head is most accurately expressed by calculating the percentage relation between the arithmetic mean of head length, breadth and height and the trunk height. According to the averages of this proportion in the last column of Table II, man is characterized by the relatively largest head and the lower catarrhines by the relatively smallest one. In individual cases, however, some of the apes equal or surpass some human beings in this respect (Table I). Thus, in one gibbon and in one orang-utan the average diameter of the head amounts to exactly one third of the height of the trunk, whereas in the Hawaiian to only 29.1 per cent.

In all newborns the head is proportionately much larger than in adults. In human newborns the percentage relation between head diameter and trunk height averages 59. In several newborn gibbons and orang-utans the corresponding figures are even higher (about 61), as has been shown in another paper by the author.[5] For this reason the heads of apes appear more human in early than in late stages of growth. Indeed, many newborn apes have as high a forehead as any adult man, a fact clearly shown by Fig. 9. This high forehead is retained throughout growth in modern man, whereas in the apes it disappears soon after birth in consequence of the insignificant postnatal enlargement of their brains.

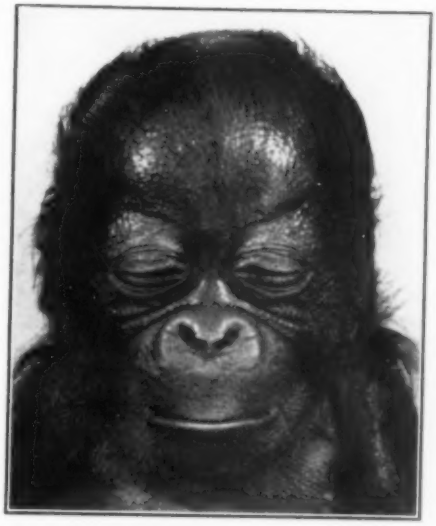

FIG. 9. FRONT VIEW OF HEAD OF NEARLY FULL-TERM FETUS OF AN ORANG-UTAN (NO. 153973, NATIONAL MUSEUM).

[5] A. H. Schultz, "Fetal Growth of Man and other Primates," *Quarterly Review of Biology*, I, 1926.

TABLE II

AVERAGES OF SOME BODY PROPORTIONS IN PRIMATES, CALCULATED FROM THE FIGURES IN TABLE I

Group of primates	Trunk height (mm)	Chest circumfer. / Trunk h.	Chest br. / Chest depth	Arm length / Trunk h.	Leg length / Trunk h.	Arm length / Leg length	Hand br. / Hand l.	Aver. head diameter / Trunk h.
Platyrrhines	206	104.2	99.3	124.4	111.5	110.5	32.3	24.7
Lower catarrhines	356	107.1	86.6	119.3	107.4	110.8	33.3	21.3
Gibbons	251	150.9	117.2	237.1	147.8	160.2	25.0	27.2
Siamang	248	160.0	120.5	234.1	131.4	178.1	29.4	29.4
Orang-utan	461	181.1	127.0	199.6	118.2	169.1	32.4	28.2
Chimpanzees	458	171.4	124.0	173.5	128.3	135.3	34.8	26.6
Gorilla	705	206.7	145.7	153.7	112.4	136.5	58.6	22.2
Man	499	162.9	123.9	149.1	167.1	89.2	41.6	32.0

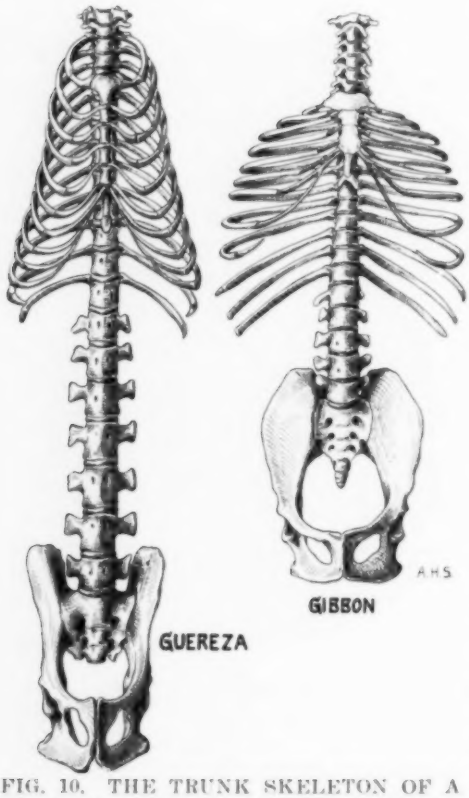

FIG. 10. THE TRUNK SKELETON OF A GUEREZA MONKEY AND OF A GIBBON REDUCED THE SAME AMOUNT.

TRUNK

In all primates, with the exception of extremely rare individual variations, the number of vertebrae in the neck is 7. In contrast to this, the numbers of vertebrae in the other regions of the spine vary a great deal not only in individuals but also in the different families and genera. This has already been shown in regard to the tail. In the adjoining sacral region a number of vertebrae have fused into one rigid structure by which the spine is fastened to the pelvis. In the monkeys of the New and the Old World the sacrum is usually composed of three vertebrae, two and four occurring only in exceptional cases. In gibbons and siamangs the average number of sacral vertebrae has increased to 4.4, and the range of variations extends from 3 to 6. In anthropoid apes and man the minimum and maximum have again increased, namely to 4 and 7, respectively, and the averages have shifted to above 5. According to the latest figures[6] these averages are higher in chimpanzee (5.4) and gorilla (5.5) than in man (5.2). These notes suffice to demonstrate that with the general advance of primate evolution more and more vertebrae tend to solidify into the sacrum. It is significant that this progressive sacralization of vertebrae has reached an even greater extreme in two of the anthropoid apes than in man.

In the remaining portion of the spine, which comprises the vertebrae of the chest and loins (thoracolumbar vertebrae), a general tendency prevails toward reduction in the number of segments. Among platyrrhine and catarrhine monkeys 19 of these vertebrae are most commonly found. In some platyrrhines (night monkey) there occur even 22 thoracolumbar vertebrae, whereas in the specialized spider monkey the average has become reduced to 17.9, quite a few individuals possessing only 17. As in so many other respects, the gibbons furnish the "missing link" between the lower catarrhines, on one hand, and the anthropoid apes and man, on the other. Their average number of trunk vertebrae amounts to 17.8 and the variations range from 16 to 19. Among the four largest primates, cases with 19 of these vertebrae have completely disappeared; indeed, no case with even 18 vertebrae has ever been recorded for orang-utan. With this elimination of these retarded and primitive numbers the pendulum of variations has begun to swing toward lower and progressive numbers. Only 16 trunk vertebrae occur in about 3 per cent. of human spines and even only 15

[6] A. H. Schultz, "The Skeleton of the Trunk and Limbs of Higher Primates," *Human Biology*, II, 1930.

in an occasional chimpanzee and gorilla (1 to 2 per cent.) and in 15 per cent. of orang-utans. The average number of these vertebrae has become reduced to 17.0 in man and even farther in the large apes, namely to 16.8 in chimpanzee, 16.6 in gorilla and 16 in orang-utan.

In regard to all these features of the spine, man has been found to resemble most closely the anthropoid apes, but in every instance the general evolutionary trend has carried one or several of the latter even beyond the stage reached by the former. These are merely a few of a long list of conditions which reveal man as a rather conservative primate in comparison with his anthropoid cousins.

The trunk of the higher primates has become relatively shortened by means of the gradual elimination of vertebrae, which allowed the pelvis to shift toward the chest (Fig. 10). In addition and probably in direct connection with this evolutionary process, the trunk of the higher primates has become very stout and broad as compared to the trunk of lower primates. This widening of the trunk, involving the width between the shoulders, the diameters of the thorax and of the pelvis, etc., is already very pronounced in the gibbons, as is strikingly shown by Fig. 10. How sharply primates can be divided into those with slender trunks and narrow chests and those with stout trunks and broad chests is best demonstrated by means of accurate measurements and their interrelations. During the past decade the author has carefully measured many hundreds of dead and embalmed monkeys and apes, including practically every group of primates. Not until recently has he been able to study fully adult gorillas in the flesh. This long hoped for opportunity came with the return of the Columbia University-American Museum African Expedition, when the author was generously permitted to study the enormous bodies of the two male mountain gorillas, brought from the Belgian Congo. With this addition it is possible for the first time to give the exact body proportions of adults of all types of higher primates and of most of the lower ones, all measured in a strictly uniform manner.[7] For the present purpose it must suffice to discuss only a few proportions in a small series of specimens, selected to represent the different types of the *Simiae*. These data are listed in Table I, and the averages thereof in Table II.

The degree of stoutness of the trunk is best shown by the percentage relation between the chest circumference (at the

[7] A. H. Schultz, "The Technique of Measuring the Outer Body of Human Fetuses and of Primates in General," *Contribut. to Embryology*, No. 117, Carnegie Instit. Wash., 1929.

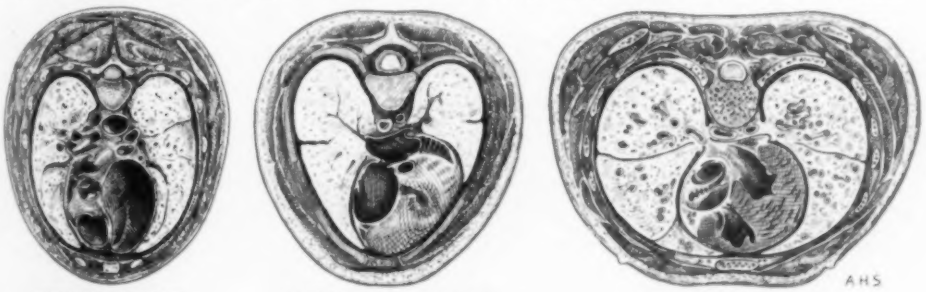

FIG. 11. CROSS SECTIONS THROUGH THE CHEST OF AN ADULT MACAQUE, A HUMAN FETUS AND AN ADULT MAN

ALL REDUCED TO THE SAME CHEST DEPTH.

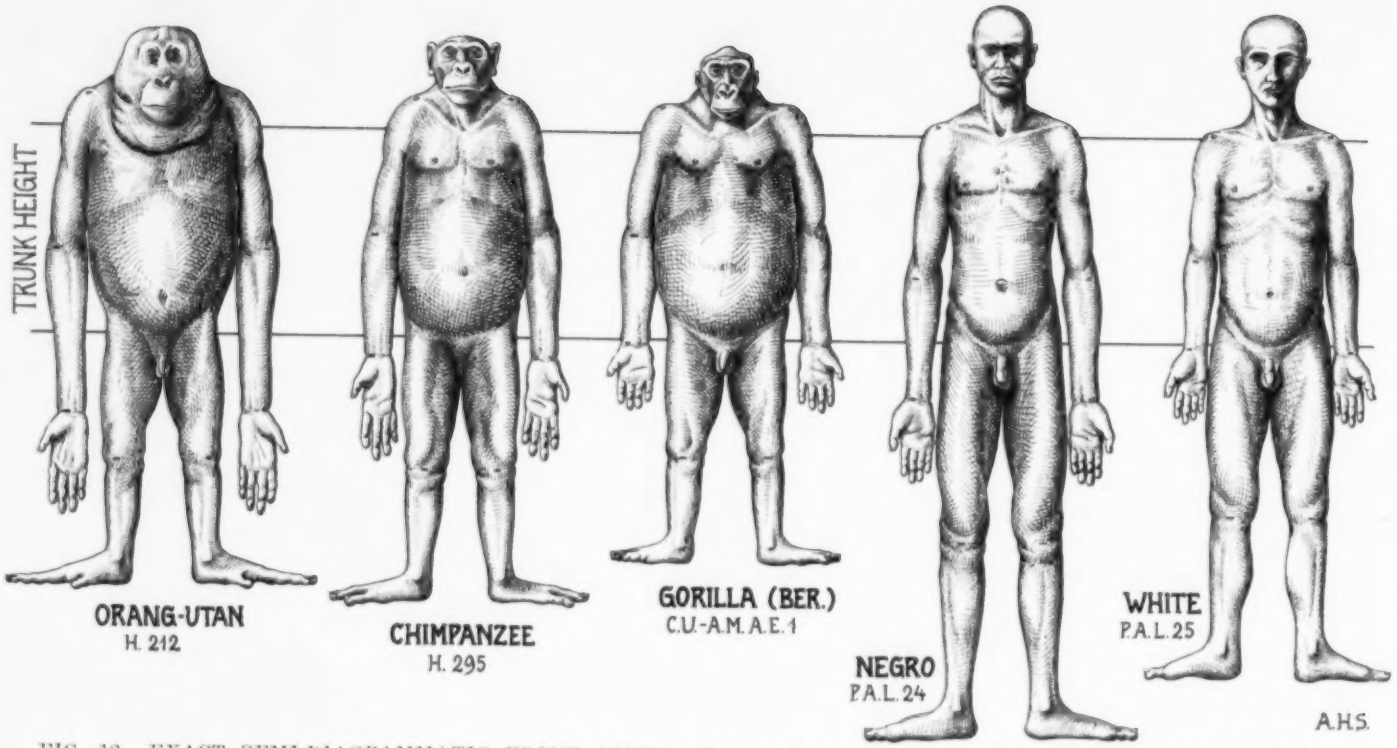

FIG. 12. EXACT SEMI-DIAGRAMMATIC FRONT VIEWS OF THE FOUR LARGEST PRIMATES AT FULLY ADULT AGE

CONSTRUCTED FROM DETAILED MEASUREMENTS ON ACTUAL SPECIMENS, DRAWN WITHOUT THE HAIR, ALL REDUCED TO THE SAME ANTERIOR TRUNK HEIGHT.

level of the fourth pair of ribs) and the height of the trunk (second column of figures in the tables). Among the lower New and Old World primates this index lies frequently below 100, indicating a long and slender trunk. The isolated maximum of 144 is attained by male howler monkeys which possess by far the bulkiest trunk of all platyrrhines. In the gibbons the average of this index has increased to above 150, in man to 163, and in the large apes to even much higher figures. In the gorilla the chest circumference is on an average more than twice as great as the height of the trunk.

In young fetuses of all primates the width of the chest equals approximately the depth of the chest, so that a cross-section appears to be roughly circular. As shown by the examples in Fig. 11, the chest shape of the lower primates changes comparatively little in the course of growth, whereas in man the chest grows much more intensively in width than in depth. The chest shape is accurately expressed by the percentage relation between the chest breadth and the chest depth (third column of figures in the tables). In platyrrhines this index averages about 100, in the lower catarrhines only 87, but in the gibbons it has changed to 117. In man and chimpanzee the transverse chest diameter amounts on an average to 124 per cent. of the sagittal one, in orang-utan to 127 per cent. and in the gorilla even to 146.

These notes on the trunk have shown without exception that the higher primates as a group have become differentiated from the lower ones by a gradual reduction in the number of presacral vertebrae, by a marked widening of the shoulders, chest and pelvis, and by an enormous increase in chest breadth as compared to chest depth. In regard to all these features man falls within the range of variations among gibbons and anthropoid apes; indeed, in a sense he represents the "missing link" between the former and the latter. Again, therefore, we have no choice in assigning man a place among the primates. This place is determined by the striking similarities in the conditions of the trunk between man and the three large apes.

Relative Lengths of the Limbs

The length of the limbs in relation to the height of the trunk varies enormously among primates. Thus, the total length of the arm, from shoulder joint to tip of the longest finger, amounts to only 95 per cent. of the trunk height in a squirrel monkey, but to 251 per cent. in a white-handed gibbon (see fourth column of figures in the tables). The total length of the leg, from great trochanter to sole, in percentage of the trunk height (next column of figures) varies not quite so extensively, the minimum of 92 occurring again in the squirrel monkey and the maximum of 192 being represented by a Negro. These figures alone go to show that the great relative length of the human leg is not as extreme a specialization as the enormous proportionate length of the arm in gibbons.

The total arm length of the great majority of quadrupedal monkeys with a long trunk amounts to anywhere from 100 to 130 per cent. of the trunk height. The typical condition (about 115) is represented by the capuchin among platyrrhines and the common macaque among the lower catarrhines. This percentage can be increased either (to about 145) by shortening the trunk, as in the howler and probably the Celebes macaque, or (to as much as 184) by lengthening the arms in direct response to the habit of swinging by the arms, as in the woolly and spider monkeys. Both these processes have most likely combined in producing the unparalleled

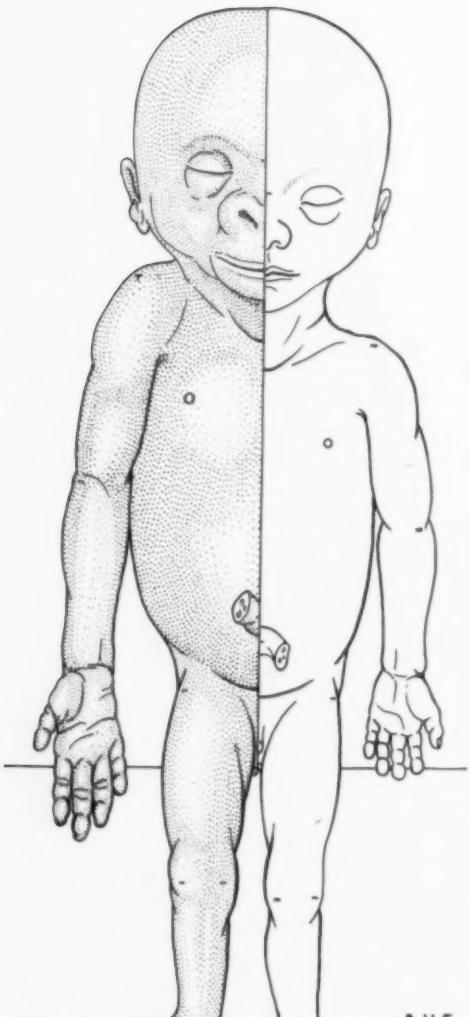

FIG. 13. EXACT BODY PROPORTIONS OF THE FETUS OF A LOWLAND GORILLA (LEFT HALF) AND OF A HUMAN FETUS (WHITE) OF THE SAME STAGE OF DEVELOPMENT (4TH MONTH)

REDUCED TO THE SAME SITTING HEIGHT.

relative arm lengths (192 to 251) of the most extreme brachiators, the gibbon, siamang, and orang-utan. Chimpanzees have also acquired proportionately longer arms (173) than any of the lower primates, except the spider monkey. Some individual chimpanzees, however, can possess relatively shorter arms (166) than some human beings (Negro = 174). The same is found in regard to the East-African or mountain gorilla. The larger specimen of the two measured by the author has a relative arm length of only 148 which practically equals that of a Chinese (146) and lies far below that of the body of a Negro, chosen at random for this study. Fig. 12 illustrates clearly this difference, according to which an ape can have proportionately much shorter arms than a man, a finding which is quite contrary to our previous beliefs.

When this paper was ready for the press the author was generously permitted by Professor William K. Gregory and Doctor Dudley J. Morton to measure also the three splendid bodies of adult male West-African or lowland gorillas, the last specimens to arrive from the recent Columbia University-American Museum African Expedition. Of the many results, gained by this unique opportunity, it is possible to mention here only that a number of striking differences were found between the two types of gorilla. Thus, the relative arm length of the three lowland gorillas amounts to 180.3, 183.1, and 187.5, respectively, *i.e.*, to more than in most chimpanzees, whereas in the mountain gorilla this percentage averages only 153.7. It is particularly significant that in regard to this proportion one species of gorilla (*G. beringei*) stands closer to man than to the other species of gorilla (*G. gorilla*).

The relative length of the leg is shorter than that of the arm in all the primates, except man, but it should be kept in mind that the arm length includes the entire hand, whereas the leg length only a small part of the foot. In all the monkeys and in the anthropoid apes the relative total length of the

lower limb varies only between 92 and 137. In the gibbons and man alone has this percentage become increased to higher figures, in the former chiefly in consequence of the shortening of the trunk, whereas in the latter predominatingly through a great lengthening of the limb itself. The striking difference between man and the three large apes in regard to the relative length of the legs is at once apparent in Fig. 12. This difference, however, loses in significance through the following observations. In the white-handed gibbon the relative length of the leg is 153, whereas in the body of a perfectly normal Hawaiian in the Hopkins collection it is only 151. In other words, there are some human beings with a relative leg length no greater than in some gibbons. The difference between the relative leg length of 192 in a Negro and that in the Hawaiian is far greater than the difference which exists in this respect between the latter and all gibbons as well as most chimpanzees. Furthermore, in newborn man the relative length of the lower limb averages only 116, which is roughly the same as in adults of most monkeys. During fetal life man and gorilla have still the same leg length, as is shown by the example in Fig. 13. As the unequaled length of the lower limb of adult man does not appear until late in growth (Fig. 14), it can not have been acquired until comparatively late in evolution.

For a proper interpretation of the significance of the lengths of the limbs they are studied not only in relation to the length of the trunk but also in relation to one another. This latter relation is obtained most accurately by expressing the total arm length in percentage of the total leg length (sixth column of figures in the tables). In platyrrhine as well as catarrhine monkeys this proportion averages 110; *i.e.*, the arm is ten per cent. longer than the

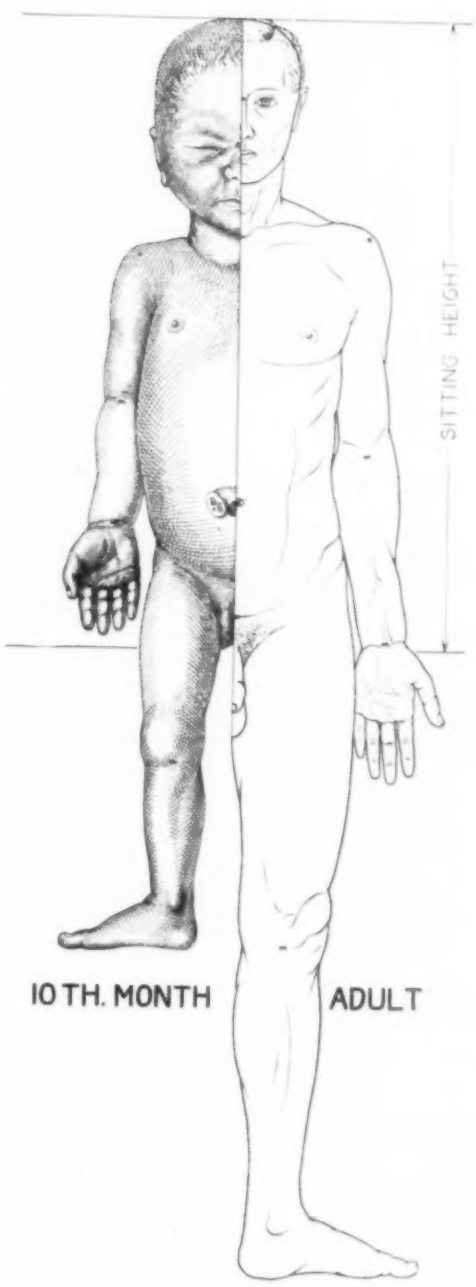

FIG. 14. EXACT BODY PROPORTIONS OF A HUMAN NEWBORN AND OF AN ADULT MAN

BOTH REDUCED TO THE SAME SITTING HEIGHT.

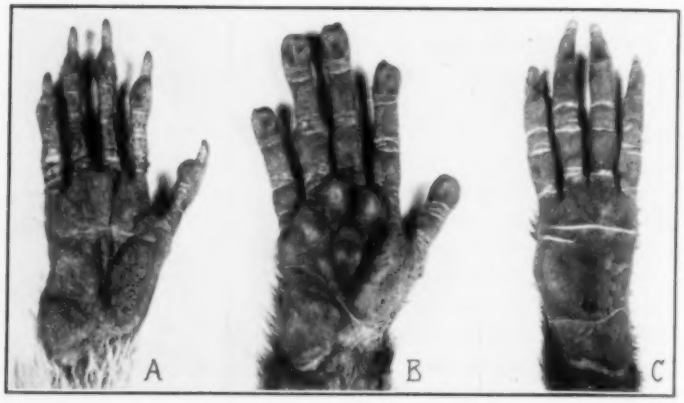

FIG. 15. HANDS OF *A* = MARMOSET (NO. 230); *B* = NIGHT MONKEY (242); *C* = SPIDER MONKEY (248 *a*) (LEFT HAND)
ALL FROM CENTRAL AMERICA.

FIG. 16. HANDS OF *A* = LANGUR (180); *B* = PROBOSCIS MONKEY (68).

leg. In all the gibbons and anthropoid apes this percentage has become increased to at least 130, a value which occurs among lower primates only in the extreme brachiator, the spider monkey. The highest of all figures are found in the most expert "hangelers," the gibbons, siamang, and orang-utan, in which the arms have become extremely lengthened as an adaptation to their special mode of locomotion. The lowest of all figures, as was to be expected, are restricted to the most perfect bipedal walker, man, whose legs have become extremely lengthened in connection with his unique type of progression. In newborn man this proportion lies still above 100, as in all adult monkeys and apes, and it is only during postnatal growth that it drops below 100, a unique condition among primates.

From all considerations it seems most likely that the original and as yet little specialized Simiae possessed the following approximate limb proportions: With the trunk height equaling 100 the

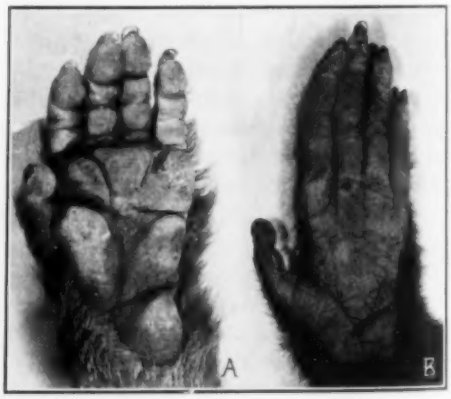

FIG. 17. HANDS OF *A* = BABOON (27); *B* = SIAMANG (NO. 255980, NATIONAL MUSEUM).

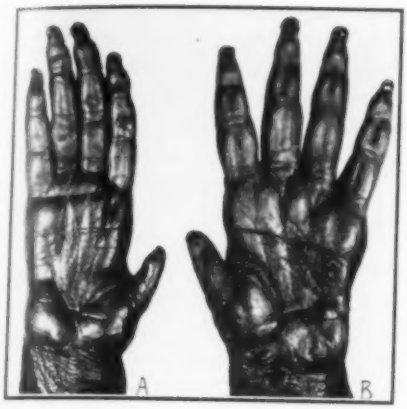

FIG. 18. HANDS OF TWO ORANG-UTANS
A = ADULT MALE (212); *B* = JUVENILE MALE (37). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

FIG. 19. HANDS OF TWO CHIMPANZEES
A = JUVENILE MALE (163); *B* = ADULT FEMALE (295). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

total arm length was 120, the total leg length 109, and, consequently, the proportion between arm and leg length 110. As shown by Table II, these (hypothetical) values persisted without significant change in most monkeys of the Old and New Worlds. The only noteworthy exceptions are the American woolly monkey and, particularly, the spider monkey in which all three original indices have become markedly increased. This represents an evolutionary experiment among the platyrrhines which has been repeated among catarrhines in a much more extreme manner in the gibbons and orang-utans. This particular trend in primate evolution to increase the relative length of both the upper and the lower limb has been at work not only among the types just mentioned but among all higher catarrhines, including man. These increases are the result of two distinct but cooperating factors: (1) a proportionate shortening of the trunk and (2) a new

FIG. 20. HANDS OF TWO GORILLAS
A = ADULT MALE LOWLAND GORILLA (CAST BY THE AUTHOR OF SPECIMEN LENT BY MUSEUM OF COMP. ZOOLOGY, HARVARD UNIV.); *B* = ADULT MALE MOUNTAIN GORILLA (CAST SENT BY AMER. MUSEUM OF NATURAL HISTORY).

FIG. 21. HAND OF AN ADULT MALE NEGRO (P. A. L. 26)
THUMB UNUSUALLY LONG FOR NEGRO.

and active growth of the limb, stimulated by its particular requirement for specialized locomotion. The relative arm length of man has increased from the original hypothetical 120 to 150, and the relative leg length from the original 109 to 167. The latter increase of 58 index units is not nearly as great as the increase of 117 index units (from 120 to 237) in the relative arm length of the gibbons. Similarly, the percentage relation between the arm and the leg length amounted to approximately 110 in the conservative ancestral Simiae; in adult man it has decreased to 89 or by 21 units; but in the siamang it has become changed much more, having increased to 178, or by 68 units.

It has been shown that the ranges of individual variations in the relative length of the arm overlap in man and the mountain gorilla, and that this character has evolved to much greater extreme in the other apes than in man. The relative length of the leg is greater in man than in the other primates, though individual gibbons can equal some human beings in this respect. Man's evolutionary specialization in leg length has not reached nearly such an extreme as the gibbon's specialization in arm length.

Hand

As shown by the accompanying series of photographs (Figs. 15 to 21), the primate hand is a comparatively constant and uniform structure, even though many details have become changed in the higher types according to definite evolutionary trends. In the primitive marmosets (Fig. 15 A) the fingers still bear long and slender claws, rather than nails. In many of the American monkeys the touch pads on the palm are still very conspicuous, as, for instance, in the night monkey (Fig. 15 B). With the exception of the spider monkey, the thumb of platyrrhines is of considerable length, reaching beyond the palm; it is not rotated to face the other digits and, therefore, is not opposable; it always branches from the palm near the base of the index finger. These are all primitive conditions, appearing in the hands of young fetuses of all primates, but persisting to adult life only in the monkeys of the New World. The second finger of all platyrrhines is much shorter than the fourth. As a rule the middle finger is longer than all the others, but in the saki and uakari monkeys the fourth finger has become the longest. In the spider monkey (Fig. 15 C), the most highly specialized platyrrhine, the thumb has become eliminated, except for some vestigial bones hidden within the hand. In only two of a great many spider monkeys, collected by the author, there still exists a small and functionless outer thumb.

In contrast to platyrrhines the thumb of the monkeys of the Old World has become opposable and its place of attachment to the palm has shifted from the base of the index finger toward the wrist (Figs. 16 and 17 A). It never reaches beyond the most distal point of the palm and in such forms as the langurs (Fig. 16 A) and, particularly, the guenons it has become reduced to a practically useless appendage. This evolutionary trend to reduce the thumb has reached its extreme not only in the American spider monkey but again in the African guereza, in which there is rarely any outer thumb left, except during fetal stages of growth. In a few catarrhine monkeys, particularly the largely terrestrial baboons (Fig. 17 A) and macaques, the touchpads are still well developed even in adults. In all lower catarrhines the index finger is shorter than the fourth finger and the latter is nearly as long as the middle digit.

The hand of the higher primates, from gibbon to man, conforms to the

type of hand in lower catarrhines by possessing a thumb which has become twisted to oppose the other digits and which branches from the palm at a place near the wrist, thereby further facilitating true opposability. The thumb of the siamang (Fig. 17 B), the orang-utan (Fig. 18), and the chimpanzee (Fig. 19) has shifted farther away from the base of the second digit than has the thumb of gorilla (Fig. 20) and of man (Fig. 21). In none of the siamangs and large apes does the thumb reach to the end of the palm; only in some gibbons can it project that far. Man is the only higher primate and, indeed, the only catarrhine in whom the thumb extends beyond the most distal point on the palm. In regard to this relative length of the thumb man differs strikingly from all three large apes. Yet the short thumb of a chimpanzee, for instance, is still of good use. Many a time the Hopkins chimpanzees have been observed to extract dexterously small splinters in the skin by means of their thumb and index finger. The gibbons, siamang, and man are the only simians in which the second finger can be as long as, or even longer than, the fourth finger, but there are many individuals in which the general rule of "finger IV > II" still holds true.

From the photographs of primate hands it can be seen that gorilla and man have the broadest hands of all primates. This is most conclusively demonstrated by the figures in the second last column of the tables, which express the breadth of the hand in percentage of the length of the hand. Among the monkeys the narrowest hand (relative breadth = 25) is found in the best brachiator, the spider monkey, and the broadest hand (38) in the most terrestrial form, the baboon. Among the highest primates the hand is again relatively narrowest (27) in the most perfect brachiators, the gibbons, and proportionately broadest in the least arboreal forms, man (42) and mountain gorilla (59). In regard to this index gorilla is much farther removed from all other primates than is man. Incidentally, it is well known that the relative breadth of the human hand varies a great deal individually. The author has become convinced from his measurements on very extensive series of other primates that the hands of monkeys and, particularly, apes vary individually and racially at least as much as does the hand of man. This is merely indicated by the examples in figures 18 and 19 and by the data in Table I.

It has been shown that the hand of man is in every respect the hand of a catarrhine primate. That it evolved from a more primitive type of hand, such as persists in platyrrhines, is a necessary conclusion from many observations. For instance, in human fetuses well developed touch pads make a passing re-appearance, the thumb still branches from the base of the second digit and is not yet rotated to face the

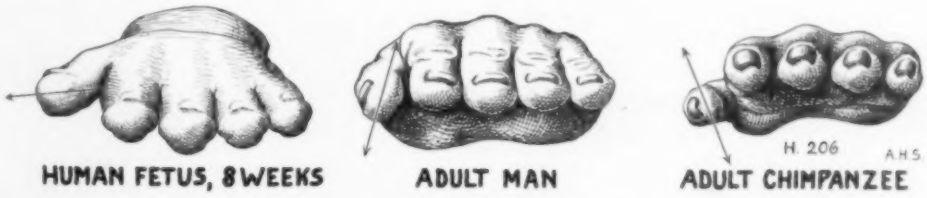

FIG. 22. FRONT VIEWS OF HANDS OF A HUMAN FETUS, AND ADULT MAN, AND AN ADULT CHIMPANZEE

THE STRAIGHT LINES INDICATE THE TRANSVERSE AXIS OF THE THUMB, AS DETERMINED BY THE NAIL.

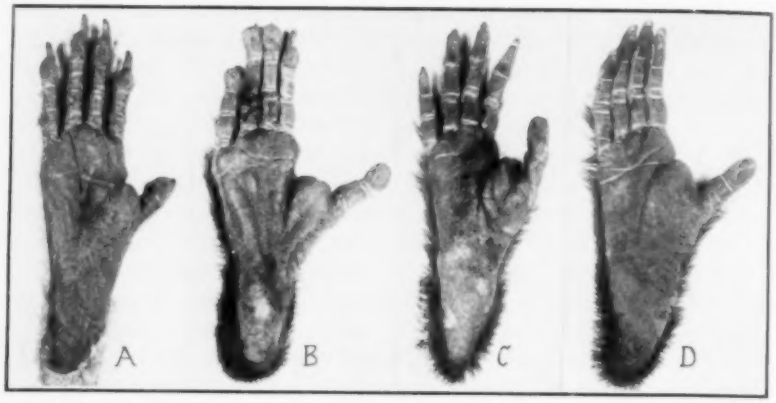

FIG. 23. FEET OF *A* = MARMOSET (230); *B* = NIGHT MONKEY (242); *C* = CAPUCHIN (249 *a*); *D* = SPIDER MONKEY (248 *a*)

ALL FROM CENTRAL AMERICA.

FIG. 24. FEET OF *A* = LANGUR (180); *B* = PROBOSCIS MONKEY (68).

other fingers (Fig. 22). The degree of opposability attained by the human thumb in adult life is less than that acquired by some adult chimpanzees, as shown by the example in Fig. 22. That adult man possesses the relatively longest thumb of all catarrhines represents a far smaller departure from the general condition than the opposite extreme, consisting in the complete loss of the thumb in the guereza. If, finally, the human hand appears broad alongside the long and slender hands of monkeys and most apes, its breadth seems very conservative in comparison

FIG. 25. FEET OF *A* = BABOON (200); *B* = SIAMANG (NO. 255980, NATIONAL MUSEUM).

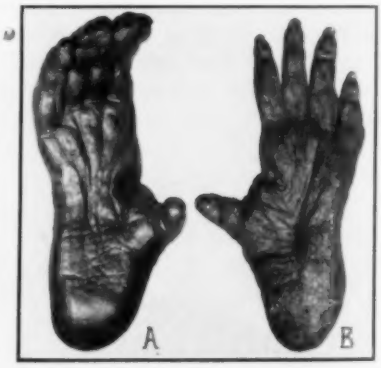

FIG. 26. FEET OF TWO ORANG-UTANS *A* = ADULT MALE (212); *B* = JUVENILE MALE. (37). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

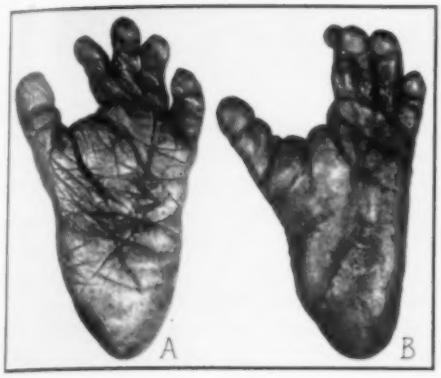

FIG. 27. FEET OF TWO CHIMPANZEES
A = JUVENILE MALE (163); *B* = JUVENILE MALE (162). PHOTOGRAPHED FROM PLASTER CASTS BY THE AUTHOR.

with the excessive broadening of the enormous hand of gorilla.

FOOT

The foot of primates is somewhat less uniform than the hand, though none of the five digits on the foot have become lost in any primate. In all New World monkeys the foot is long and slender, the great toe is short, abduced, and very little rotated, and the digits II to V are much lengthened (Fig. 23). The second toe is never as long as the third, which is generally the longest of all five toes. In most marmosets (Fig. 23 A), uakaris, sakis, and night monkeys, however, the fourth toe surpasses even the third in length. In the marmosets and tamarins the "great toe" appears almost rudimentary in comparison with this toe in the higher platyrrhines.

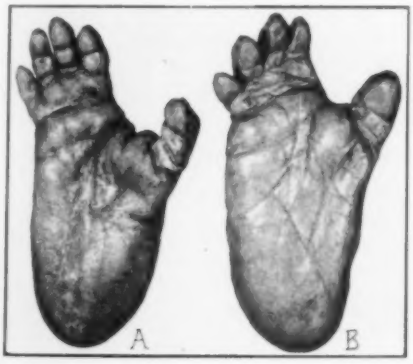

FIG. 28. FEET OF TWO GORILLAS
A = ADULT MALE LOWLAND GORILLA (CAST BY THE AUTHOR OF SPECIMEN LENT BY MUSEUM OF COMP. ZOOLOGY, HARVARD UNIV.); *B* = ADULT MALE MOUNTAIN GORILLA (CAST SENT BY AMER. MUSEUM OF NATURAL HISTORY).

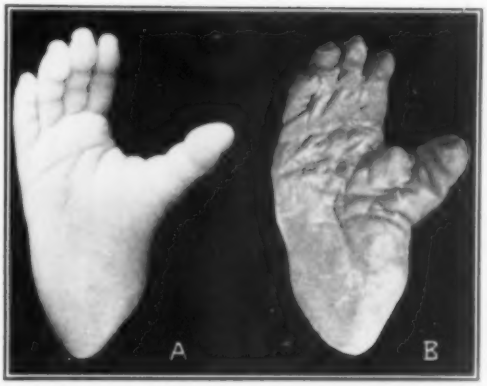

FIG. 29. FEET OF TWO GORILLA FETUSES
A = LOWLAND GORILLA, 89 MM SITTING HEIGHT (No. 7698, CARNEGIE MUSEUM); *B* = MOUNTAIN GORILLA, 205 MM SITTING HEIGHT (FROM A PHOTOGRAPH SENT BY PROF. I. BROMAN).

The foot of Old World monkeys (Fig. 24) is very similar to that of the

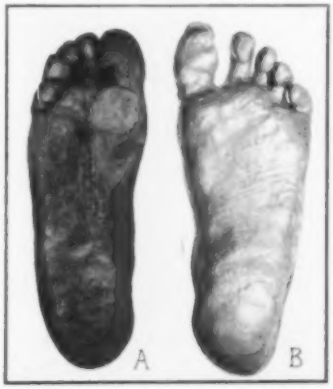

FIG. 30. FEET OF *A* = ADULT MALE NEGRO (P. A. L. 26); *B* = ADULT MALE AUSTRALIAN ABORIGINAL (P. A. L. 15) (CAST OF SPECIMEN SENT BY PROF. A. L. BURKITT).

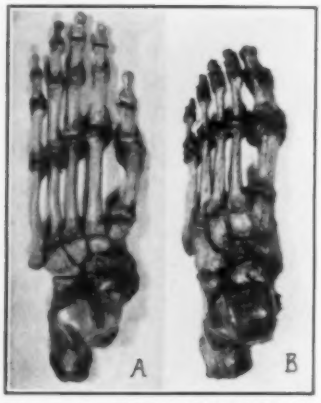

FIG. 31. FOOT SKELETON
A = MOUNTAIN GORILLA; *B* = NEGRO.

higher American monkeys. As in the latter, the foot is long and slender, the great toe is proportionately short, and the second to fifth toes are greatly lengthened in all the arboreal forms, though fairly short in the terrestrial baboon (Fig. 25 A). In many of the catarrhine monkeys the second toe is as short as, or shorter than, even the fifth, and the fourth toe is often as long as, but very rarely longer than, the third (Fig. 24).

The foot of the gibbons and the siamang (Fig. 25 B) differs from that of the lower catarrhines chiefly in regard to the relative length of the first toe. This toe is of very considerable length in the siamang and proportionately still longer in most gibbons. In this group, for the first time, can the second toe equal or surpass the fourth in length. In all siamangs and a variety of gibbons the second and third toes are united by a cutaneous web, a condition which appears occasionally in man and is then inherited.[8]

Among all the many platyrrhine and catarrhine monkeys, the gibbons and the siamang the outer foot is more uniform than it is among the anthropoid apes and man. The Figs. 26 to 30 demonstrate best the remarkable adaptability to special function of the foot in the largest of the primates. The opposite extremes are represented by the most arboreal form, the orang-utan, and the most terrestrial, man. These extremes are connected by intermediate stages, existing in the feet of chimpanzee, lowland gorilla, and mountain gorilla. In the orang-utan the second, third, and fourth toes have become proportionately longer even than in the gibbons. The phalangeal bones within these digits are curved and perfectly adapted for grasping around the limbs of trees. The great toe of orang-utan has shifted farther back toward the ankle than in any other simian, and has degenerated at least as much as in the marmosets. In many orang-utans the great toe has lost its nail and one of the normally two phalanges. In the chimpanzee the great toe is well developed and in some specimens it can reach even to the end of the middle segment of the second toe (Fig. 27 A). The lateral toes are not nearly as long as in the orang-utan and the sole is relatively broader than in monkeys. In the lowland gorilla (Fig. 28 A) the foot has become even broader and the digits II to V are proportionately shorter than in chimpanzees. The sole extends forward to nearly the end of the basal segment of the third toe. In the mountain gorilla (Fig. 28 B) the sole reaches even farther, *i.e.*, almost to the base of the terminal phalanges, which is at least as far as in man. The free portion of the great toe of the lowland gorilla is still longer than in the mountain type, but in the latter the great toe projects farther forward than in the former on account of its greater *total* length. As shown by Fig. 29, these marked differences between the feet of the two gorilla species are already well defined in fetuses.

[8] A. H. Schultz, "Zygodactyly and its Inheritance," *Jour. Heredity*, XIII, 1922. W. L. Straus, Jr., "The Nature and Inheritance of Webbed Toes in Man," *Jour. Morphol. and Physiol.*, XLI, 1926.

In all the anthropoid apes the middle toe is the longest and the second toe usually shorter than the fourth, but at times equally long or even longer. In man the second or even the first toe has become the longest of all, but only in the course of growth, since in young human fetuses the great toe is as yet short and much abduced and the middle toe is frequently seen to project beyond all others. The relative length of the free portion of the great toe in the Australian (Fig. 30 B) differs less from that character in the mountain gorilla (Fig. 28 B) than the latter differs in this respect from a chimpanzee (Fig. 27 B). The great toe of man does not branch from the most distal point of the sole, since its place of attachment has not yet reached entirely the base of the second digit. In all adult primates the outer great toe has been found to branch from the sole proximally to the base of the second toe. In orang-utan this point of branching lies closest to the ankle and in man closest to the second toe, the mountain gorilla differing in this respect more from the former than from the latter.

The peculiarity of the human foot is due principally to two evolutionary changes which followed the loss of the grasping function: (1) The nearly complete adduction of the great toe and (2) the unequaled shortening of the phalanges of the toes II to V. The adduction of the great toe is not yet present in the human fetus and the joint at the base of this toe is still curved and pointing toward the side in man, as in the apes with a movable great toe (see Fig. 31) and for further details the paper quoted in footnote (6). The shortening of the lateral toes is best shown by quoting a few averages of the percentage relation between the length of the phalanges of the middle toe and the total foot length. In monkeys these phalanges form approximately 38 per cent. of the total length of the foot skeleton, in gibbons 41 per cent., in orang-utan 43 per cent., in chimpanzee 36 per cent., in gorilla not quite 33 per cent., but in adult man only 21 per cent. In the human fetus, however, this percentage is still 33. These toes of man, therefore, become proportionately much shorter during the development of the individual, just as they became reduced in the course of the evolution of the species. As shown by the example in Fig. 31, this evolutionary shortening has affected most of all the middle phalanges, which are completely lacking in some persons and fused with the terminal phalanges in many other human beings.

It is due to this shortening of the lateral toes that the great toe of man has acquired the distinction of being as long as, or longer than, all the other toes. That the second toe of man equals or surpasses the third in length is no greater a specialization than that other evolutionary trend by which the fourth toe has become longer than the middle one in a variety of the lower platyrrhines.

According to all anatomical and embryological comparisons the foot of man can be nothing else but a modification of a type of foot which has also given rise to the feet of modern anthropoid apes.

Conclusions

Man's place within the mammalian order of primates can not be understood and properly evaluated without as close a study of all the monkeys and apes as of man himself. A comprehensive census of all the simian primates would result chiefly in a long list of the large variety of monkeys scattered over the tropical and subtropical zones. Appended to this list would be the names of a few higher primates. All the monkeys represent a multitude of different minor specializations with here and there some type attempting to rise above the others. They are all just "monkeys," have tails, a dense coat of hair, a slender trunk, narrow hands and feet,

a very limited intellect, and many other quite primitive features. This, in spite of many detailed distinctions, comparatively uniform majority of primates contrasts sharply with the small minority: the gibbons, apes, and man. This second and outwardly heterogeneous group has been carried many evolutionary steps above the level attained by even the highest of the large first group. All the evidence from comparative anatomy and embryology points toward one common origin for this second class of simians. From this ancestral stock they must have soon spread along more or less diverging courses, even though they inherited many of those general tendencies which not only had started but also continued to lift them above the rest.

Of this select company the gibbons have undoubtedly progressed least and the siamang but little more. In many characters they have preserved evolutionary stages intermediate between certain little differentiated catarrhine monkeys and the anthropoid apes, particularly the orang-utan. Man and the three large apes share the distinction of representing the few most advanced experiments in all primate evolution. In some respects man has become more highly specialized than the apes, but in regard to many other features this relation is reversed.

These conclusions are supported and illustrated by the examples of evolutionary trends which have been discussed in this paper. A few of the clearest and most significant trends are briefly summarized in the accompanying tabulation.

It seems hardly necessary to state as a final conclusion that man is one of the few higher primates and resembles most closely the anthropoid apes, particularly the gorilla and chimpanzee, a resemblance which is in general greater than that existing between the large apes and the monkeys.

GENERAL TREND

Character	*from* most primitive condition among monkeys	*to* condition in large apes and man	Extreme in:
Body size	small	large	gorilla
Hair	very dense	relatively sparse	man
Tail	long	extremely reduced	gibbon
Spine	few sacral vertebrae many thoracolumbar vert.	many sacral vertebrae fewer thoracolumbar vert.	gorilla orang-utan
Trunk	slender	stout	gorilla
Chest	narrow	broad	gorilla
Upper limb	short	long	gibbon
Lower limb	short	long	man
Hand	slender	slender to very broad	gorilla
Thumb	very little opposable attached near 2nd finger	opposable shifted toward wrist	man and chimpanzee gibbon
Foot	slender	slender to broad	gorilla
Toes II to V	long	very long very short	orang-utan man

RHENIUM[1]

By Dr. WILLIAM F. MEGGERS
U. S. BUREAU OF STANDARDS

It is a long step from the four elements, "earth, air, water and fire," of the ancient Greek philosophers to the 92 chemical elements now recognized as a group of elementary substances from which all bodies are made. Through many centuries the concept of elements has developed, gradually changing to correspond to newly discovered facts so that at the present time the word itself has acquired a new meaning. The chemical elements are now regarded as a series of atomic systems increasing in weight and complexity from hydrogen to uranium.

A small number of chemical elements were known in prehistoric times; the list includes silver, gold, carbon, copper, iron, mercury, lead, sulphur and tin. No doubt their discovery was purely accidental. The middle-age alchemists probably deserve some credit for discovering arsenic, bismuth, phosphorus, antimony and zinc, but the remainder of the known chemical elements have been discovered since the beginning of the eighteenth century, when chemistry became a true science. The complete story of these discoveries is as interesting as any adventure or romance ever narrated. Just now one of the final chapters of this story has been written; it deals with the discovery and description of rhenium.

The atomic conception of matter is also very ancient. Some of the Greek philosophers of the third and fourth centuries B. C. taught "that all substances are formed of indivisible particles or atoms which are eternal and unchangeable, that the atoms are separated from one another by void, and that these atoms, by their combinations, form the matter we are conscious of."

[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

The prestige of Aristotle who believed matter to be infinitely divisible and continuous is responsible for delaying any development of the idea until the seventeenth century when the work of Boyle, Newton, and others laid the foundation of analytical chemistry. During the next two centuries, chemical methods and technique were perfected at a remarkable rate, important laws were discovered and knowledge was classified so that it became possible to characterize and distinguish different chemical elements with great refinement. Thus by the end of the nineteenth century, 85 different elements had been identified and described.

In the second half of this period a new method of detecting and identifying chemical elements was announced by Bunsen and Kirchhoff. It is based on the observation that each chemical element, when rendered luminous in the gaseous state and viewed with a spectroscope, exhibits colored images or lines which are uniquely characteristic of the element. With the aid of spectral analysis several new elements (rubidium, caesium, gallium, indium, thallium, and some of the rare gases) were discovered.

Another factor which has played an important rôle in the discovery of new chemical elements is the so-called periodic classification which was stated in essentially its present form by Mendeléev in 1871. Although earlier attempts had been made to correlate chemical properties of elements with atomic weights, Mendeléev was the first to recognize combining power (valency) as the outstanding periodic property of the elements. On this periodic classification, in which the elements are now arranged in eight vertical groups having valency from 1 to 8, is

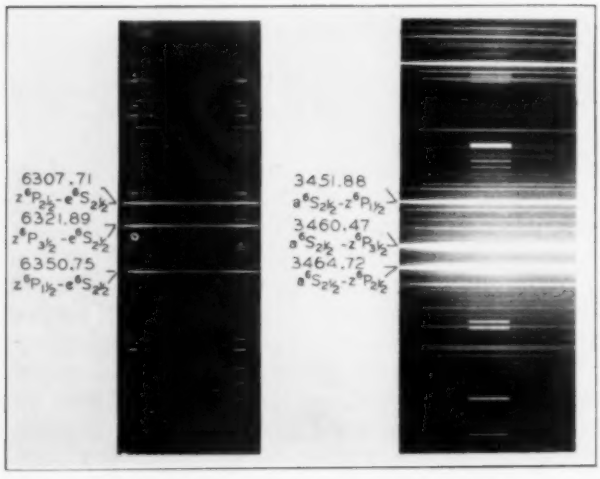

FIG. 1. TWO TRIPLETS IN THE ARC SPECTRUM OF RHENIUM, ONE IN THE ULTRA-VIOLET (3451.88, 3460.47, 3464.72A) AND THE OTHER IN THE RED (6307.71, 6321.89, 6350.75A). THEY ARE ENLARGED TO THE SAME FREQUENCY SCALE TO SHOW THAT ONE ATOMIC ENERGY STATE (z^6P) IS COMMON TO BOTH TRIPLETS. TRANSITIONS FROM THIS THREEFOLD EXCITED STATE TO THE NORMAL STATE OF THE ATOM (a^6S) GIVE RISE TO THE FIRST TRIPLET, WHILE TRANSITIONS TO A STILL HIGHER EXCITED STATE (e^6S) ACCOUNT FOR THE SECOND TRIPLET. THESE GROUPS OF LINES GAVE THE CLUE TO THE STRUCTURE OF THE SPECTRUM AND OF THE ATOM. THE LINE AT 3460.47A IS THE MOST SENSITIVE ONE FOR DETECTING RE, IT WILL DISCLOSE A SINGLE RE ATOM IN THE PRESENCE OF 30,000,000 OTHER ATOMS.

based practically the entire modern system of chemical knowledge and also the scientific theories of the electronic structure of atoms. Certain blank spaces in the periodic system as constructed by Mendeléev corresponded to unknown chemical elements, thus giving the first clue to the number and nature of different elements which were still undiscovered.

Only at one place in the periodic system as originally proposed was there an uncertainty as to the number of elements in a period. This was in an exceptionally long period containing a group of elements known as the "rare earths," all of which have the same chemical valency. Laborious methods of separation disclosed more and more elements of this type without suggesting any definite limit to their number.[2] Such a limit was finally imposed in 1913 by Moseley's discovery that the characteristic Röntgen spectra change from element to element in a continuously progressive manner. Following this discovery each chemical element was assigned an atomic number, beginning with hydrogen 1 and ending with uranium 92, and it was seen that only six (atomic numbers 43, 61, 72, 75, 85 and 87) remained unknown.

The identification of chemical elements by means of their Röntgen spectra furnished a new method of attack on the unknown ones—hafnium 72 being discovered in this way in 1923, and the only remaining unknown rare earth, 61, detected in the same way a few years later. This left only four possible chemical elements to search for and two of these, 85 and 87, are probably radioactive, extremely unstable, and too scarce to be detected by any of the recognized methods now available. Thus, finally, only two theoretical atomic numbers, 43 and

[2] The total number of rare earths is now known to be 14; they are cerium, praseodymium, neodymium, illinium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutecium.

75, offered any promise of adding further members to the family of known chemical elements. Indeed, these two, among others, were predicted by Mendeléev in 1869; they were referred to as eka-manganese and dvi-manganese because they represented blank spaces under manganese in the periodic classification of the elements. Many attempts, both chemical and spectroscopic, had been made to detect these homologues of manganese, but none were successful until 1925, when two German chemists, Walter Noddack and Ida Tacke, announced[3] that both 43 and 75 had been chemically concentrated from platinum ores and rare-earth minerals, and had been identified by their Röntgen spectra. The newly detected elements were named masurium (Ma, 43) and rhenium (Re, 75) after the east and west boundaries of Germany.

The discoverers of 43 and 75 proceeded on the assumption that these elements had not been discovered heretofore because of their extreme scarcity, estimating that the earth's crust should contain about 1 part in a million million (10^{-12}) of 75 and 1 part in 10 million million (10^{-13}) of 43. Guided by the predicted chemical properties, Noddack and Tacke carefully carried out planned chemical processes with selected ores and minerals until a sufficient concentration of the new elements revealed their presence by the appearance of accurately predicted lines in the Röntgen spectra. The discovery was announced when a minute quantity of material estimated to contain about 0.5 per cent. masurium and 5 per cent. rhenium furnished the following table of Röntgen spectra, in which wave-lengths are expressed in Angstrom units (10^{-10}m):

Apparently little progress has been made in further concentration and purification of masurium, but the supply of rhenium has increased in an astonishing manner. Only 2 mg of rhenium had been purified in 1927, about 120 mg were

[3] W. Noddack and I. Tacke, *Naturwissenschaften* 13, p. 567; 1925.

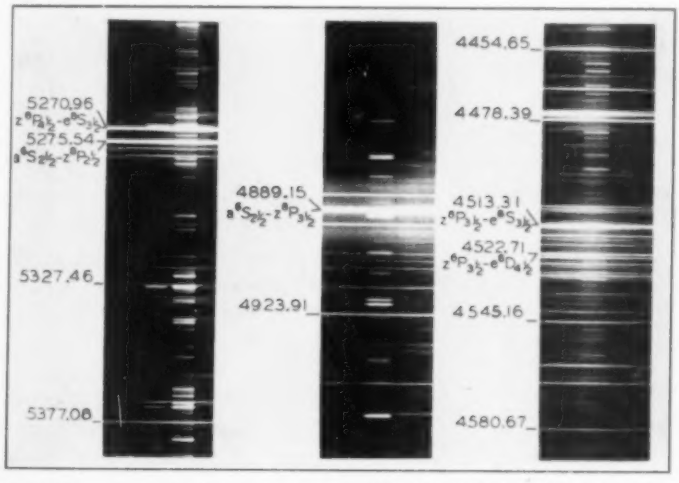

FIG. 2. PORTIONS OF THE ARC SPECTRUM OF RHENIUM IN THE BLUE AND GREEN

THE LINES AT 5275.54 AND 4889.15A ARE THE MOST EASILY EXCITED LINES OF RHENIUM. THE SYMBOLS, $a^6S_{3\frac{1}{2}} - z^6P_{3\frac{1}{2}}$, REPRESENT THE TYPE OF ATOMIC ENERGY CHANGE WHICH PRODUCES THE PARTICULAR LINE. THE ATOMIC ENERGY STATES OF RHENIUM ARE, IN GENERAL, POLYFOLD AND THE MAXIMUM MULTIPLICITY CAN BE EITHER 4, 6 OR 8. THE SHORT LINES SUPERPOSED ON THE RE SPECTRA IN FIGS. 1 AND 2 BELONG TO THE IRON ARC SPECTRUM, WHICH IS USED AS A STANDARD SCALE FOR MEASURING THE WAVE LENGTHS OF LINES IN OTHER SPECTRA.

	Masurium 43			Rhenium 75				
Line symbol	K_{α_1}	K_{α_2}	K_{β_1}	L_{α_1}	L_{α_2}	L_{β_1}	L_{β_2}	L_{β_3}
Measured Wave-length	0.672	.675	.601	1.4299	1.4407	1.235	1.2048	1.216
Calculated Wave-length	0.6734	.6779	.6000	1.4306	1.4406	1.2355	1.2041	1.2169

prepared in 1928, the production of an entire gram was described in 1929, while the possibility of an annual production of 120 kg as a by-product from a single chemical plant was announced in 1930. The price of rhenium was about $10,000 per gram in 1928; in 1929 it fell to $50, and in 1930 to $3 per gram.

Along with the increasing availability of rhenium has come an extensive accumulation of facts as to its chemical and physical properties.[4] A large number of chemical compounds of rhenium have been prepared and studied. For example, it has been found that rhenium prefers a valency of 7 or 6; its higher oxides are more stable than those of manganese. Burning rhenium in a stream of oxygen gas produces a series of oxides as follows: white oxide (Re_2O_8), yellow oxide (Re_3O_7), red oxide (ReO_3), blue oxide (Re_3O_8), and black oxide (ReO_2). The last, when heated to 800° C. in hydrogen, reduces to rhenium metal. Rhenium metal can also be prepared by reduction of the sulphide or of potassium or ammonium perrhenate. Especially simple and efficient is the reduction of potassium perrhenate ($KReO_4$). Only minute quantities of rhenium are obtainable as a cathode deposit in electrolysis. Tests of the stability of the metal in the presence of oxidizing gases at high temperatures show that rhenium is considerably more noble than tungsten. It dissolves readily in nitric acid (HNO_3), slowly in sulphuric acid (H_2SO_4), and practically not at all in hydrofluoric (HF) and hydrochloric (HCl) acids. The atomic weight of rhenium has been determined to be 186.31. Its atoms have been found[5] to consist of 2 isotopes with mass numbers 185 and 187, as was expected from the general rule that complex elements of odd atomic number (above 9) consist of 2 odd mass numbers 2 units apart; but this is the first element analyzed in which the heavier isotope is the more abundant, the ratio being estimated as 1.62 to 1. These are only a few of the new facts which rhenium has brought to chemistry.

We shall now review very briefly what has been learned about the physical properties of this new element: Its melting point has been determined to be $3440° \pm 60°$ on the absolute scale of temperature. Although this temperature is high it is about 250° lower than the melting point of tungsten. The density of rhenium metal is about 21 times that of water, its crystal form is hexagonal and its atomic radius is 1.382A. The metal possesses some ductility and can be hot forged and rolled. The specific electrical resistance of rhenium at ordinary temperature is 0.21×10^{-4} ohm cm $\pm$ 15 per cent., four times that of tungsten. The temperature expansion coefficient is found to be 2.7 times greater in the direction of the crystal axis than at right angles to it, *viz.*, 12.45×10^{-6} and 4.67×10^{-6}. The electron emission of rhenium has been

[4] I. and W. Noddack, *Zeit. Angew. Chem.*, 125, p. 264, 1927; *Zeit. Elektrochemie*, 34, p. 627, 1928; *Naturwissenschaften*, 17, p. 93, 1929; C. Agte, H. Alterthum, K. Becker, G. Heyne, and K. Moers, *Zeit. Anorg. Allgem. Chemie*, 196, p. 129, 1931. This is by no means a complete list of publications on the properties of rhenium, but the papers listed here will be found to contain references to other publications.

[5] F. W. Aston, *Nature*, 127, p. 591, 1931.

measured in the temperature range 1900° to 2700°K; it emits only $\frac{1}{8}$ to $\frac{1}{4}$ as strongly as tungsten, or with the same intensity as tungsten at a temperature 150 to 200° lower.

Perhaps the most important and interesting property of any atom is its power to emit or absorb radiation; this importance arising from the fact that such radiation identifies an element uniquely, and interesting because it reveals the electronic structure of the atom. Of course, everybody knows that the quondam "indivisible" atom has been subdivided into protons and electrons, the unit positive and negative electrical particles (or waves), which are now regarded as the unresolvable ultimates. According to a theory proposed by Bohr in 1912, the atoms resemble the solar system in that a nucleus (consisting mainly of protons) corresponding to the sun is surrounded by electrons in definite orbits like the planets. From this concept of an atom the "quantum theory of spectroscopy" has been developed to account for the observed monochromatic radiations emitted by atomic systems. On the basis of this theory a spectral line corresponds to a definite change in energy of an atomic system; indeed the frequency of the radiation multiplied by a universal constant (h) is exactly equal to the energy change. The changes of atomic energy were assumed to represent changes in the orbits of the planetary electrons, and, guided mainly by a few known facts of optical spectra, Bohr was able to outline a process of atom building which specified the number of electrons and described the orbit of each that entered into the structure of an atom. In this way the periodic classification of the chemical elements was arrived at from spectroscopic data, and the road to further knowledge about atoms was paved. During the past five or six years different types of atomic energy changes (usually called spectral terms) have been recognized;

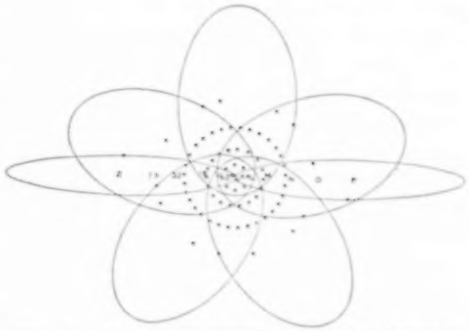

FIG. 3. THE RHENIUM ATOM ACCORDING TO BOHR'S THEORY

AND RECENT DEVELOPMENTS IN THE CORRELATION OF SPECTRAL STRUCTURE WITH ELECTRON CONFIGURATIONS IN RADIATING ATOMS. THE NUCLEUS IS A TINY SPECK IN THE CENTER OF THE FIGURE. THIS IS SURROUNDED BY 75 ELECTRONS GROUPED IN SUCCESSIVE SHELLS AS SHOWN, THE OUTERMOST GROUP CONSISTING OF 7 VALENCE ELECTRONS FOR WHICH THE ORBITS ARE DRAWN. RÖNTGEN SPECTRA ORIGINATE WITH ATOMIC ENERGY CHANGES OCCURRING WHEN ELECTRONS IN THE INNER SHELLS K, L, M, ETC., ARE DISPLACED FROM THEIR NORMAL POSITION, WHILE THE OPTICAL SPECTRUM IS PRODUCED BY ORBITAL CHANGES OF THE OUTER ELECTRONS. THE ACTUAL DIAMETER OF THE Re ATOM IS ABOUT 0.000000001 INCH.

these have been correlated with electron orbits and configurations so that all spectroscopic phenomena are now assigned to definite atomic systems and activity. This development has made it possible to infer the structure of an atom from the analysis of its spectrum.

The first spectral data for rhenium were the Röntgen lines already quoted; they constituted the first proof of the existence and capture of this new element. Investigations of the Röntgen spectra of rhenium were soon extended and in 1928 detailed descriptions had been published.[6] In the same year the discoverers announced that the arc and spark spectra of rhenium were qualitatively known and that several hundred lines were known certainly to belong to it. No further information was given except that the ultimate lines of the optical spectrum serve to detect rhenium in

[6] H. Beuthe, *Zeit. Physik.*, 50, p. 762, 1928.

concentrations down to 1 part in 10 millions. The last statement suggests that the optical spectrum is of considerable practical importance in the search for rhenium-containing ores or minerals because the ultimate line of the optical spectrum is probably the most sensitive test for rhenium that can be found. The Noddacks assert that the optical spectrum is sensitive to 10^{-7} while the Röntgen spectrum can not detect rhenium in concentrations less than 2×10^{-4}. Examination of 1600 minerals from all parts of the world has revealed rhenium in 100 of them but never more than 0.001 per cent. or 10^{-5}. This explains why all attempts to detect rhenium in minerals by means of Röntgen spectra failed until Noddack and Tacke conceived the plan of first enriching 1,000 fold by chemical processes the concentration which might be expected in certain minerals. It also accounts for the entire absence of rhenium lines from tables of the characteristic spectra of other chemical elements, a case quite different from hafnium which was first identified by recognition of its predicted Röntgen spectrum in ordinary zirconium minerals, and was later found to have been represented for many years by hundreds of lines in the emission spectrum tables ascribed to zirconium. The natural concentration of hafnium in zirconium ores averages several per cent., while no ores contain more than 0.001 per cent. of rhenium, so that the difference in behavior is due to great disparity in concentration rather than to a difference in sensitivity of the ultimate spectrum lines.

Spectral lines of hafnium were positively identified with faint lines in the solar spectrum but a similar comparison of rhenium with Fraunhofer lines disclosed no coincidences. This does not disprove the presence of rhenium in the sun, it only indicates that the concentration of rhenium in the reversing layer of the sun's atmosphere is less than 10^{-7}. The earth's crust consists of about 10^{-5} hafnium and, according to the latest estimates, of about 10^{-9} rhenium. If we assume the same ratio to exist in the sun the detection of hafnium lines in the solar spectrum and the failure to find rhenium lines are both fully explained.

A complete and accurate description of the optical spectrum of rhenium, and the analysis of its structure, are the latest contributions[7] to our knowledge of the properties of this new atom. The light of an electric arc in which rhenium is vaporized has been photographed with the largest spectrographs at the Bureau of Standards; about 3,000 new lines ranging in wave length from 2,100 A in the ultra-violet to 8,800 A in the infra-red have thus been added to the data of spectroscopy. The relative intensities of these have been estimated on a scale ranging from 1 to 2,000 and practically all the stronger lines have been accounted for as transitions between atomic energy states, many of which have been identified with electron configurations in the atom. Thus it has been established that the normal state of the rhenium atom is described by a spectral term associated with 7 valence electrons, and certain excited states are definitely identified with orbital changes of one or more of these outer electrons. Series-forming terms have been recognized which permit a calculation of the ionization potential of the rhenium atom. This is a measure of the stability of the group of valence electrons. It is expressed as the potential difference through which a free electron must fall to acquire sufficient energy to remove one of the valence electrons upon collision, and for rhenium atoms it is found to be 7.85 volts. Some of the more prominent and significant lines of the rhenium spectrum are shown in Figs. 1 and 2, and as a crowning achievement a picture of the rhenium atom as deduced from its optical spectrum is given in Fig. 3.

[7] W. F. Meggers, *B. S. Journ. Res.*, 6, p. 1027, 1931 (R. P. 322).

THE MATHEMATICAL WEAKNESS OF THE EARLY CIVILIZATIONS

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DURING the last few years the mathematical public has enjoyed at various times the invigorating experience of changing its mind as regards the mathematical attainments of the ancient Babylonians and the ancient Egyptians. A number of new discoveries relating thereto have been announced in a historical publication inaugurated in 1929 under the title "Quellen und Studien zur Geschichte der Mathematik" which appears in two series entitled "Quellen" and "Studien" respectively. The first volume of the former series (1930) is devoted to a translation into German of the noted Moscow Mathematical Papyrus by Professor W. W. Struve. It may be of interest to note here that on page 181 thereof, Professor Struve makes the following comment which is in disaccord with the view commonly expressed: "In no case can the Babylonian mathematics be regarded as on a higher level than the Egyptian, even if we should soon become acquainted with more formulas from the cuneiform inscriptions than from the hieratic papyri."

This relatively favorable view as regards the ancient Egyptian mathematics was based to some extent on the widely different character of the sources of our present knowledge relating to the mathematics of the ancient Babylonians and the ancient Egyptians. Professor Struve pointed out that in the case of the former our knowledge is based on what appears in large collections which may have been royal or temple libraries, and, therefore, on what was probably the best of the periods concerned, while in the case of the latter it is based on scattered discoveries which may not represent the most advanced attainments of their times. Judging from the material actually available at the present time there seems to be no question as regards the relative superiority of the Babylonian mathematics, as was pointed out by Professor O. Neugebauer on page 325, volume 1 (1930), of the "Studien" noted above.

One of the most instructive studies in the history of mathematics relates to the values used by various peoples for the ratio of the circumference of a circle to its diameter. It is well known that in this respect the ancient Egyptians are supposed to have excelled all other pre-Grecian nations since they assumed that the area of a circle is equal to that of a square whose side is eight ninths of the diameter of the circle. This implies that the ratio in question is the fourth power of four thirds and some mathematical historians have assumed that the ancient Egyptians realized this implication. A much cruder value for this ratio is the number 3 which appears in the literature of various ancient countries, including Babylonia, and is also found in our Bible. It would not have required a very carefully planned experiment to exhibit the inaccuracy of this and every other assumed value for this ratio on the part of the pre-Grecian mathematicians, but as far as is now known such an experiment was never made before the times of the ancient Greeks notwithstanding its simplicity.

The fact that very crude approximations for the value of the ratio of the circumference of a circle to its diameter were commonly employed even in medieval times, and were often regarded as

accurate, seems to imply that credulity rather than experimentation has been the prevailing trait of the human race, especially in the early civilizations. By measuring the circumferences and the diameters of the wheels of their chariots with care they could readily have found that the commonly assumed values of this ratio are inexact and it is somewhat surprising that those who constructed these chariots did not point out the inaccuracy in such prevailing views relating thereto. The recent discoveries relating to the mathematical attainments of the ancient Babylonians and the ancient Egyptians make it more desirable to emphasize the noted shortcomings since otherwise these discoveries would be apt to convey an incorrect impression of the true situations.

A true picture of the mathematical attainments of ancient civilizations implies an emphasis on the evidences of weakness as well as on the evidences of strength. In the histories of mathematics the attention is too frequently confined to the latter. For instance, in his work noted above Professor Struve stresses the relative accuracy of the supposed value used by the ancient Egyptians for the ratio of the circumference of a circle to its diameter as compared with that used by the ancient Babylonians. It is, however, more important to note that there is no evidence tending to show that even a single pre-Grecian mathematician discovered a method for finding the value of this ratio to any desired degree of accuracy. In this respect all the pre-Grecian mathematics is on a level and exhibits the same lack of coordination of theoretical and applied mathematics. In fact, the various assumptions in regard to this ratio furnish one of the clearest illustrations of a tendency towards pure mathematics in ancient times. It was much easier to make assumptions or to accept the statements of others relating thereto than to test their accuracy by actual measurements.

One of the most striking recent discoveries relating to the ancient Egyptian mathematics is the very early use of the theorem that the area of a hemisphere is equal to that of two great circles of the same sphere. It is, however, somewhat misleading to say that the ancient Egyptians had a correct rule for finding the area of a hemisphere since there is no evidence tending to prove that they could find the area of a circle to any desired degree of accuracy. In view of the crudity of their rule relating to the latter as judged from the modern point of view it does not seem justifiable to assume that they were able to prove the remarkably elegant theorem that the area of a sphere is equal to that of four great circles of the same sphere. At any rate, it is very important to bear in mind that, in the pre-Grecian mathematics which has become known to us, proofs are almost completely lacking and that this is an outstanding evidence of weakness in their mathematical developments as compared with those of modern times.

Mathematics has become a republic by means of its proofs since these have enabled the individual to build his own storehouse of mathematical knowledge. Real proofs in mathematics are, however, impossible without postulates. Up to the present time we have no evidence tending to prove that any explicit use of mathematical postulates was made before the period of Greek mathematical activity or that any pre-Grecian mathematician realized the need of such postulates. While the ancient Babylonians and the ancient Egyptians reached an advanced stage of civilization along certain lines, their extant mathematics is woefully lacking as regards some of the elements which are most fundamental. They did, however, deal with a number of abstract mathematical notions including that of positive rational numbers. In fact, the ancient Babylonians used

also sexagesimal fractions and paid much attention to converting common fractions into the form of sexagesimal fractions as has been proved recently by Professor O. Neugebauer in the "Studien" noted above.

According to these "Studien" we now know at least 19 Babylonian problems which give rise to quadratic equations and with respect to ten of these the details of the solutions are given. In some cases the method used corresponds to the modern method of completing the square and differs only from our modern procedure by omitting the double sign when the square root is extracted. All the earlier accounts, relating to the historical development of the quadratic equation have become antiquated during the last three years as a result of these discoveries relating to the mathematical attainments of the Babylonians during a period of at least 1,500 years, beginning about 2000 B. C. It is especially interesting to observe that this period overlaps that of the early Greek mathematical activity and hence the said discoveries establish a continuity in algebraic developments which had not been known to exist hitherto.

A remarkable element of weakness common to all the mathematics preceding the Christian era and extending several centuries beyond this period is the lack of the use of negative numbers. The nature of these numbers is so painfully and powerfully illustrated by debts as well as by distance in an opposite direction from those represented by the positive numbers that one can see that their usefulness could have been observed comparatively early in the development of abstract mathematics. It is therefore noteworthy that even the ancient Greek mathematicians, to whom we owe so many fundamental theorems of elementary mathematics, failed to extend the number concept so as to include the negative numbers and that this extension can not be regarded as really completed until about the beginning of the nineteenth century. Even such noted mathematicians as H. Cardan (1501–1576) and R. Descartes (1596–1650) sometimes reasoned very erroneously in regard to these numbers since the former tried to prove that $-a \times -b$ could not be equal to $+ab$ and the latter thought that negative numbers increased with the increase of their absolute values.

Elementary mathematics is a kind of intellectual currency which people commonly employ, like monetary currency, at its stamped values without much thought as regards the underlying structure. It is true that in mathematics we now aim to explain the fundamental principles, but teachers of this subject usually recognize at every examination of their classes that their efforts have been only partially successful. Hence much of the mathematics which is being used at the present time is imperfectly understood by many of those who are using it and the comparatively large amount of mathematics that is being used at the present time is largely due to the complexity of our civilization and not to an intrinsic interest in mathematical thinking. The fact that much less mathematics was employed in the ancient civilizations, therefore, does not reflect so much a lack of intellectual interest in this subject as a less urgent need of the type of intellectual currency represented by mathematics. In dividing by a fraction many persons invert the denominator and multiply because they were taught a rule to this effect and not because they comprehend the reason for this rule, which does not seem to have been explicitly formulated until several centuries after the beginning of the Christian era.

Our modern idea of mathematics is that it is mainly concerned with the formulations and proofs of general theorems. Both of these fundamental notions are almost completely lacking in

the pre-Grecian mathematics. For instance, in the addition of common fractions it is now customary to reduce these fractions to their lowest common denominator and then to add the numerators thereof, but this rule has not yet been found in an explicit form even in the rich mathematical literature of the ancient Greeks. It is well known that the Rhind Mathematical Papyrus of the ancient Egyptians is largely devoted to operations with special common fractions but when such fractions are added they are sometimes considered with respect to a number which is not divisible by the denominators of all the fractions involved in the operation. It would obviously be unfair to regard the mathematics of the ancients as inferior to our own just because their methods differ from those now commonly employed, but the stating and proving of general theorems is not affected thereby and hence we have here definite evidence of weakness of the mathematics of the ancients as compared with that of modern times.

This weakness is only slightly affected by the recent discovery of the facts that the ancient Babylonians used the so-called Pythagorean theorem and that the ancient Egyptians used a rule for finding the volume of the frustum of a square pyramid which is equivalent to our modern formula relating thereto. The laboratory of the mathematician is his brain and its development depends on its use and not on an expensive physical equipment. It is therefore not surprising to find even in ancient times isolated instances of relatively advanced mathematical developments. In a primitive state of civilization such developments naturally attracted little attention. Even at the present time the mathematician reaches directly only a small number of interested persons and the new results of his work are usually preserved as a consequence of a very widely organized effort to disseminate useful knowledge and to simplify the determination of what is actually new. The history of the development of mathematics constitutes one of the most reliable and most suggestive aids to the study of the intellectual development of the human race.

Mathematics is a concomitant of civilization and the concept of number may antedate the beginning of the development of a language. Even some of the lower animals have exhibited a kind of number concept and primitive people are sometimes able to count far beyond their number words. Hence the reader may be surprised when he meets a statement like the following: "Not until modern times was unity considered a number," D. E. Smith, "History of Mathematics," volume 2, page 26, 1925. In the commonly accepted sense of the term unity was clearly regarded as a number by the ancient Babylonians as well as by the ancient Egyptians. It is, however, obviously possible to give a definition for the term number so as to exclude unity from the concepts involved therein and this was sometimes done by the ancient Greeks and by some later writers but as far as we know now it was not done by any earlier people. In answering the question "how many?" the number one, or unity, was naturally regarded as a number just as much as two, three, etc., were regarded as numbers, and this conception of number is very old. The unique properties of unity, such as the fact that every natural number after the first can be obtained by adding unity to the preceding and that a number is not changed when it is multiplied by unity probably did not impress the people forcibly before they attained a somewhat advanced state of intellectual development.

Since mathematics is mainly a mental science a large part of the mathematical developments are lost to this world with the deaths of the individuals concerned. Comparatively few have left a record of some of their mathematical work and in

modern times such records are almost entirely confined to developments or results which are supposed to excel those left by predecessors. Hence our modern mathematics is from the nature of its development superior to that of earlier times and the relative mathematical weakness of the early civilizations is constantly becoming more pronounced. In view of the close interrelations between the various parts of mathematics, the comparative merits of ancient and modern work can perhaps be more readily seen here than in some of the other sciences. At any rate, the evolution of mathematics is definitely established notwithstanding long periods of halting and even of slight retrogressions. Our modern period of development seems to be one of unprecedented rapidity and to point to unlimited room for new advances. This applies especially to written work. Whether our progress in mental arithmetic is equally marked is difficult to determine. As far back as about 1300 B. C. the ancient Egyptians seem to have emphasized mental arithmetic as results from the following admonition: "When you calculate mentally do not allow a word to be heard."

WATER PURIFICATION AND SEWAGE DISPOSAL ON THE GREAT LAKES

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THE Great Lakes of North America, located on the border line between the United States and Canada, are the largest connected bodies of fresh water in the world. They have a combined water surface of 95,160 square miles, and their land drainage basins cover an area of 202,920 square miles. Over 64 per cent. of the water surface of these lakes lies within the boundaries of the United States.

The following table gives some interesting data for each of the lakes.

Name of lake	Greatest Length in miles	Greatest width in miles	Maximum depth in feet	Altitude above sea-level in feet
Superior	350	160	1,180	601.6
Michigan	307	118	870	579.6
Huron	206	101	750	579.6
Erie	241	57	210	570.8
Ontario	193	53	738	244.5

The outlet for these lakes is through the St. Lawrence River. Their maximum discharge, measured opposite Ogdensburg, N. Y., has been estimated as 320,000 sec. ft.; their minimum as 191,000 sec. ft.; and their mean as 210,000 sec. ft. Lake Superior, the largest single body of fresh water in the world, receives the flow from 200 rivers. The other lakes have many small streams entering them, none of which is very large.

Through the connecting straits, rivers, canals and the St. Lawrence River, a continuous waterway is provided for a distance of over 2,200 miles, as measured from Duluth to the Atlantic Ocean. The large population in the territory surrounding the Great Lakes, some of it being centered in our largest cities, the rich natural resources available for industrial purposes within adjacent land areas and the existing power and industrial developments at Niagara Falls, account for the enormous amount of waterborne traffic on these lakes. In 1926, 137,000,000 tons of raw and manufactured materials, valued at more than two

billion dollars, were carried in lake vessels. In spite of the fact that navigation of the lakes is confined to approximately seven or eight months of the year, due to shore ice at lake ports and to dangerous storm conditions during the winter months, their tremendous economic value to the United States and Canada for water transportation purposes may be realized.

The water in the Great Lakes is usually of excellent quality for public water supplies when unpolluted by sewage. It is remarkably uniform in the kind and quantity of its chemical constituents. They are moderately hard waters and do not need to be softened unless a very soft water is required for industrial purposes. They are usually free from large amounts of suspended matter, except following storms which may stir up for short periods matter deposited on the bottom. On account of their usual clarity, they are frequently infested with microscopic organisms during the warmer months of the year. These organisms require sunlight for their propagation and are a frequent source of trouble in the operation of water purification plants. From the sanitary standpoint, the natural waters of these lakes are of great purity, but, as will be shown later, the problem of securing this water for public supplies is complicated by several factors, some of which are difficult, if not impossible, to overcome.

Intakes for public water supplies on the Great Lakes are either of the submerged type or are provided with a superstructure which projects above the surface of the lake. The intake cribs are connected to the shore by either pipe lines laid in a trench on the bottom of the lake, or by means of a tunnel under the bottom of the lake. The distance from shore at which intakes are placed varies greatly. It is desirable to place intakes in not less than 20 feet of water, if possible, and preferably in 35 to 40 feet. The slope of the bottom naturally fixes the location of the crib, if these depths of water above the intake are to be obtained. Consequently, intakes are found located anywhere from 1,000 feet to six miles from shore. Where compressed air is required to construct intakes and tunnels, it is probably not practicable to work in depths of water greater than 100 feet. Shallow shore waters may become filled with stranded ice floes during the winter months; a sandy or silted bottom may cause serious difficulties by clogging intakes, intake pipes and tunnels; and anchor ice may block the ports of cribs, if they are placed in too shallow water. All these conditions have a bearing on the quality of the water which may be obtained from the lakes, and obviously necessitate the conclusion, that, although the great body of the water in these lakes may be of a high degree of purity, only the waters within a few miles of the shore are really available for public water supplies.

While the natural impurities in the lake waters are relatively small in amount, the need for their removal is now generally recognized, especially as the standards for potable waters have advanced during the past two decades. The necessity for drinking water supplies of exceptional purity, as regards their bacterial content, is of even greater importance to the water consumer, since the removal of such pollution is insurance against water-borne diseases. This phase of the problem involves the nature and extent of the pollution of the available waters of the Great Lakes by sewage and trade wastes.

With the exception of the city of Chicago, which diverts its sewage through a canal into the Des Plaines River, which empties into the Illinois River, and the latter into the Mississippi River, all the sewage from the watershed of the Great Lakes eventually finds the way into them. While treatment and natural dilution may diminish the amount and danger from the impurities in these

wastes, the fact remains that there is being discharged daily immense volumes of polluting matter into lake waters. Since from this same source is drawn the major part of the public water supplies for a large population on their shores, the danger of infection from water-borne diseases and the imperative need for the purification of water supplies are self-evident.

There have been several important investigations of the extent to which lake waters have been contaminated by sewage during the past twenty-five years. Probably the investigation which covered the greatest area was conducted by a joint commission provided by treaty between Great Britain and the United States, wherein the United States and the Dominion of Canada undertook to answer the question. "To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to public health and unfit for domestic or other uses." The second portion of the reference dealt with remedial measures. It will be noted that this investigation related only to "boundary waters between the United States and Canada."

The work was carried on during the years 1913 and 1914, and covered, so far as the Great Lakes are concerned, Lake Superior opposite Port Arthur, the St. Mary's River, the St. Clair River between Lake Huron and Lake St. Clair, Lake St. Clair, the Detroit River between Lake St. Clair and Lake Erie, the western end of Lake Erie and the latter opposite Port Stanley, the Niagara River, the western end of Lake Ontario and the eastern end where it discharges into the St. Lawrence River.

Special investigations of importance have been conducted opposite several large cities, notably those at Chicago and Cleveland. In 1924–25, the U. S. Public Health Service, in cooperation with the Sanitary District of Chicago, the Chicago Department of Health and the Indiana and Illinois State Boards of Health, carried on an investigation of the pollution of Lake Michigan in the vicinity of South Chicago and the Calumet and Indiana Harbors. Earlier investigations were made in 1908, 1909 and 1910 of this same portion of Lake Michigan and are published in the reports of the Lake Michigan Water Commission and the Indiana State Board of Health.

Three investigations of the quality of the water of Lake Erie opposite Cleveland and its suburbs were made in 1904, 1912 and 1920, respectively. The first investigation was made by the late Professor Geo. C. Whipple and was unusually exhaustive in discussing local conditions; the second study was made by Professor D. D. Jackson, of Columbia University, and the third by the writer. A second investigation of a limited area was also made by the writer in 1924, for the purpose of locating a proposed new intake for a new pumping station and filter plant for the city of Cleveland. An investigation in 1909–1911 by Alvord, Whipple and Eddy, consulting engineers for the city of Milwaukee, Wisconsin, included a study of lake currents in Lake Michigan opposite that city. Many other studies have been made for the purpose of determining local conditions of pollution and their relation to the best positions for the location of sewer outfalls and water works intakes. But the deductions which may be drawn from all the investigations which have been made clearly indicate certain definite conclusions and which may be briefly set forth as follows:

(1) That the waters of the Great Lakes are dangerously polluted with sewage along the shores opposite centers of large population, and that such waters should not be used for public water supplies without purification.

(2) That the dispersion of sewage and trade wastes from outfall sewers, the contaminated flood waters from storm sewers and the discharge of polluted rivers, is influenced primarily by the intensity, direction and duration of the

winds, by the contour of the shore line and by the slope of the bottom outward from the shore.

(3) That direct contamination of intake waters from passing vessels and from the dumping of material dredged from harbors and rivers, the waters of which are badly polluted, may be a source of danger to water supplies.

(4) That dilution of sewage and trade waste discharges with the purer water of the lake, and the accompanying biological factors tending to diminish the concentration of polluting matter, is an uncertain factor of safety, owing to the erratic and irregular diffusion of these discharges.

It may be well to point out more specifically the areas of gross pollution and to show how they are affected by lake conditions. For example, the city of Detroit and its suburbs discharge their untreated sewage into the Detroit River, which connects Lake St. Clair with Lake Erie, while the Niagara River receives the sewage of Buffalo and adjacent cities. In these rivers a well-defined current carries the pollution down stream into Lake Erie and Lake Ontario, respectively. Diffusion of the sewage, therefore, is governed largely by the factors exerted under stream-flow conditions. The western ends of these two lakes show the contaminating effect of these polluted streams for some distance from the mouths of the rivers. As the streams or connecting straits between these lakes are quite broad and the current well defined, sewage discharged from outfalls may be carried in stream lines without much diffusion for considerable distances. However, the action of the winds in setting up deflecting currents is not without its effect even here.

The conditions influencing lake water pollution opposite centers of large population, such as at Milwaukee, Cleveland, Toronto and many other of the larger towns and cities, differ somewhat from those described on the Detroit and Niagara Rivers. Dangerous contamination of shore waters in this case is produced principally by the irregular diffusion brought about by surface and sub-surface currents induced by wind action and other factors, as previously explained. Since these conditions are uncontrollable and difficult, if not impossible, to forecast, the danger of contaminating intake waters used as public supplies becomes a serious problem.

The movement of the water through the lakes is very slow. For example, with an assumed uniform flow in a cross-section of Lake Erie opposite Cleveland, the current produced would be 0.16 of a mile per day, if there was no wind acting to produce surface and sub-surface currents. This general drift of the water is negligible when compared with currents induced by wind action. It has been estimated that surface currents in the lake will have on an average a velocity of about 5 per cent. of the velocity of the wind. It is of course evident that the duration of the air currents in any one direction, as well as their intensity, will materially affect the water currents in the lakes. Onshore winds have a tendency to pile up the water along the shore, and it naturally returns as an undertow to the body of the lake. Under such conditions, it may be easily perceived how polluted water from the shore may find its way directly to water intakes, and how sewage from outfall sewers will be swept outward into the lake. On the other hand, offshore winds will carry the surface water away from the shore and will bring the purer water from beyond the zone of shore pollution toward the shore. Under such circumstances a purer water is more likely to be obtained at the intakes, although the outward flowing polluted surface water, unless rapidly dispersed, may be a source of contamination to intake waters even under these conditions.

Temperature changes in the waters of the lakes are also factors which modify the quality of the water at different periods of the year. At the bottom of a lake there is probably a stagnant layer of cold water which does not change much in temperature throughout the

year. Variations in the temperature of the water in the zone occupied by the first fifty or sixty feet from the surface probably induce vertical currents. Since wind action is not likely to stir the water below a depth of fifty feet, it is apparent that all the factors affecting dispersion of polluted waters along the shore are most active within this zone, and which is probably fortunate from the view-point of rapid natural purification processes.

The chances of intake waters being contaminated by passing vessels are not as remote as at first thought might be anticipated. The enormous traffic on the Great Lakes means that a large number of vessels pass daily within short distances of water intakes. Polluted ballast water being discharged by vessels leaving or entering the harbors, and the sewage which they may discharge in passage, is a possible source of contamination, although regulations governing these conditions are supposed to be strictly followed. The entry to the lakes of ocean vessels from foreign ports, which will result in the greater use of the St. Lawrence waterway, opens up possibilities of the introduction of cholera and other water-borne diseases, unless the strictest enforcement of quarantine regulations is observed.

From the foregoing description of the physical factors affecting the dispersion of sewage, it is evident that erratic and uncontrollable conditions exist which can not be foreseen. They can only be guarded against by the careful purification of all the water drawn from the lakes for public supplies. Natural agencies for purification afforded by the dilution of sewage with lake waters are not dependable, although such factors should be considered in the design of sewage disposal plants.

The proper correlation of sewage treatment with water purification is always to be borne in mind in solving problems dealing with the waters of the Great Lakes. Adequate treatment of sewage and trade wastes is imperative, if water purification plants are not to become overloaded. Depreciation of shore properties for bathing and residence purposes, because of the washing up on the shore of floating sewage solids, of oil and grease, plainly indicates the need for adequate treatment processes for all sewage and trade wastes discharged into the lakes. A more determined effort to preserve these great inland lakes for water supply and recreational purposes by proper and effective methods of treatment of both sewage and trade wastes, is an obligation upon all who can speak with authority upon this important sanitary problem.

DISEASE, ITS CAUSE AND PREVENTION

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BACTERIA govern the length of man's life and determine the part of the earth on which he may live. They have defeated armies and destroyed cities; nations which have been the glory of the world have gone down before them. The majority of individuals born to-day would enjoy health and live to old age were their bodies not invaded by microbes. They are no respecter of persons, nor are they governed by the edicts of rulers. However, at the command of modern science they are commencing to relinquish their hold, and some of earth's most fertile regions, where in the past the risk to the visitor was greater than the visit to a battlefield, are being transformed into tropical health resorts. Some microbes are no longer the fairy-tale adventurers of death and disease. They are being controlled; disease is being reduced, and during the past century man's expectancy of life has been doubled. Still much remains to be done, for the learning and the practicing of the laws of sanitation can prevent more suffering and save more lives than the abolition of war. Here the scriptural entreaty is especially appropriate: "Give me understanding and I shall keep the law; yea, I shall observe it with my whole heart." Each bit of knowledge gained in this field carries man one step nearer the goal where he will be the master and not the slave of his environment.

The methods used in the prevention and cure of disease are determined by man's ideas concerning the nature and cause of disease. Man's earliest conception of disease was that it was due to demons. These were supposed to enter the body of their victim and rule in a merciless fashion.

The possessed man, tossed and shaken in fever, pained and wrenched as though some live creature were tearing or twisting him within, rationally finds a personal spiritual cause for his sufferings. In hideous dreams he may even see the very ghost or nightmare fiend that plagues him. This is the savage theory of demoniac possession, which has been for ages, and still remains, the dominant theory of disease and inspiration among the lower races. It is obviously based upon an animistic interpretation, most genuine and rational in its proper place in man's intellectual history, of the actual symptoms of the case.

Such was the belief concerning disease amongst the early ancestors of modern civilized man, and such is the belief of primitive man even to-day. Logically, such a disease could be cured only by dislodging the invading demon, and what was more natural than to conclude that this could be accomplished by force or by flattery? The medicine-man attempted to force out the invader by making the habitation unbearable. The victims were whipped, loaded with chains, given ill-smelling and ill-tasting drugs, all in the hope that the demon would seek more congenial quarters. Often attempts were made to entice him out. Here charms, incantations and sacrifices played a prominent part. For centuries roots and herbs were prescribed because of their symbolic form. Curious things were used, such as moss scraped from the head of a culprit hanged in chains, or from mummies from the Egyptian tombs, or the roots of plants gathered in a graveyard during the dark of the moon. It was not until man discarded the belief that insanity is a manifestation of demoniac possession that the last vestige of the demoniac theory disappeared from the medical idea of civilized man.

Hippocrates, who is known as the

father of medicine and who lived during the fourth century B. C., was one of the first to teach that disease is due to a derangement of the body itself. He taught that the body contains four humors: blood, phlegm, yellow bile and black bile. When these were present in the right proportion, one enjoyed good health. Small variations accounted for differences in temperament; a sanguine temperament was due to a preponderance of blood; a phlegmatic to an excess of phlegm; and a bilious or melancholic temperament to a surplus of bile. Greater variations resulted in illness; hence, it was the object of the medical profession to keep the proper balance of the humors and in this way to maintain health.

Hippocrates' theories were not seriously questioned until the seventeenth century, when a flood of new theories burst forth. Some of those were even more complex and mystical than the ones they were intended to supplant. Disease was regarded as "an intestinal movement of particles," a "struggle between nature and disease-producing matter," a "lack of tone or an insufficiency of tone." There was the dynamic-organic system of Stahl, who believed that the soul was the supreme principle of disease. There was the mechanico-dynamic system of Hoffmann, which stated that life expresses itself in motion, and that all manifestations in the body are controlled by nervous spirits. The school of Montpellier taught that various organs possess individual life. Mesmer claimed that magnetic fluids flowed from the hand, and the Bremontau system asserted that all that was necessary for a cure was to determine the grade of a disease in accordance with the strength or weakness of the active irritation, and to adjust the right proportion of strengthening or weakening medicine to the case. The theory which lasted longest and had the greatest effect upon medical practice was the theory of homeopathy founded by Hahnemann (1775–1843). He defined disease as a "spiritual dynamic derangement of a spiritual vital principle." His theory was that the potency of drugs was increased by dilution, provided the dilution was accompanied by shaking. In some cases it was also supposed to be increased by pounding. Accordingly, he and his followers diluted their drugs to an enormous extent. They also tested them upon themselves. In the case of ordinary tinctures he recommended diluting two drops with 98 drops of alcohol, taking two drops of this mixture and adding 98 drops of alcohol, and repeating the process 30 times. Vershow commented on the folly of this doctrine by saying that he would defy even a German to detect beer at the mouth of the River Spree after a glass of it had been spilled into the river seven miles upstream. Hahnemann taught that in curing disease a knowledge of anatomy and physiology was unnecessary, and that pathology was a hindrance. Not only were the dosages he recommended always extremely small, but many of his preparations were of a highly poetic and romantic nature. There were: *Lachryma filia*, the tears of a young girl in great grief and suffering; *flavus irides*, the yellow rays of the spectrum, the extract of three kinds of lice, and the like. It is almost incredible that such a doctrine could exist, not to say flourish, for nearly half of the most progressive of all centuries. Yet it did, and was in the end actually an advance over some of the previous methods that had been emphasized in which prescriptions contained upward of one hundred ingredients. Some of the old prescriptions had been built up by succeeding generations of doctors, each doctor believing that he must add one or more drugs as his contribution to the prescription, or consider his life wasted. Thus, it is not

surprising to learn that homeopathy cured more than the systems it was replacing. It appeared to substantiate the statement of Oliver Wendell Holmes: "If all the drugs that had ever been used for the cure of human ills were gathered together and thrown into the sea it would be ever so much better for humanity and ever so much worse for the fishes."

As is so well stated by Kopeloff:

> This maelstrom of confused theory was finally directed into a definite current. Louis Pasteur rose like a Triton. By the brilliance of his genius, by the clearness and breadth of his vision, he formulated the bacterial or germ theory of infectious diseases which must forever dominate medicine. No longer could malevolent spirits be held responsible for disease, nor could an improper admixture of the four humors be regarded as the cause of ill health. Disease was but another example of the struggle for existence. It was life preying on life; the invasion of the macro-organism by the micro-organism.

His first contribution was the discovery of the cause and method of prevention of pebrine, a disease of the silkworm and named from the black-pepper-like spots appearing in the body of the infected silkworm. It was undertaken by Pasteur in 1865 as a patriotic duty at the request of an old friend, Dumas, one who admired, had confidence in, and could foresee Pasteur's future greatness. For five years Pasteur struggled on without sufficient equipment, facing criticism and discouragement, suffering the loss of a kind father, of two loving children, and he himself brought near the brink of the grave by a cerebral hemorrhage which left him a cripple. In spite of these obstacles, Pasteur won. He found the black specks in the body of the diseased silkworms to be the cause of their death. He found that diseased moths lay diseased eggs from which developed diseased silkworms. These soon died or were useless in the production of silk. The germs left on leaves or in dust soon perished, but the ones in the eggs survived. Pasteur proved that the disease might be ended by the destruction of all diseased eggs. To this end he devised the process of placing each female moth when ready to lay its eggs on a separate piece of linen. After it had laid its eggs and adhered to the linen it was dried, removed from the linen, ground up in water, and the water examined microscopically. If black specks were present the eggs were destroyed; if not, they were kept and in due time yielded healthy silkworms. When the method was announced the cry came back: "It is impractical." To which Pasteur impatiently answered: "Don't tell me that any one wants anything simpler than a preventive method which is to just put your eye to the eyepiece of a microscope after pounding a moth in a mortar, with a few drops of water—mere child's play, taking an hour or two to learn." But the prejudice, falsehood and bickering were overcome only by Pasteur taking over an old, badly infected, valueless (in so far as the production of silk was concerned) plantation and transforming it into a profitable, productive, disease-free establishment. By so doing he demonstrated the practicability of his method, rescued the silk industry, and saved France something like four millions of dollars yearly.

The second disease to be conquered was anthrax, a disease highly fatal and widely prevalent among the lower animals. With man it is quite rare and less fatal. It is referred to in both sacred and profane history, modern and ancient. No one knows where or when it had its origin. Until the last quarter of the eighteenth century man stood in helpless astonishment before its rapid and fatal action. Its cause was the first organism to be seen by man, the first to be obtained in pure culture and one of the first to be conquered.

In 1877 Pasteur set out to discover a

cure or prevention. For years he struggled on. He traveled through infected districts, listened to the farmers' stories, studied its natural history. He grew the micro-organism in test-tubes and proved that it could be transferred from flask to flask and still produce the disease in susceptible animals. He subjected the organism to abnormal temperatures, injected it into the bodies of animals, and found that they did not contract the disease, but on the contrary such cultures rendered the animals immune. After repeated verification of the results, and after most careful analysis, he announced to the world that he had found a prevention for anthrax. His announcement fell on the ears of scoffers and skeptics. One veterinary journal in 1881 carried the following: "Will you have some microbe? There is some everywhere. Microbiolarty is the fashion; it reigns undisputed; it is a doctrine which must not even be discussed, especially when its Pontiff, the learned M. Pasteur, has pronounced the sacramental words, 'I have spoken.'" Ridicule, sarcasm and even personal abuse was not to deter the man who had fought through sorrow and illness and who knew that he had discovered a great truth. Great indeed was the astonishment and surprise when Pasteur announced that he would submit the question to a decisive public test. Fifty sheep were to be given the virulent anthrax bacteria. One half of them were to have been previously protected by the vaccine, while the other half were not. Pasteur predicted that the twenty-five unprotected sheep would perish, while the protected ones would survive. On May 5 the animals to be protected were given their first dose of the vaccine. Twelve days later they were given a stronger dose. On May 31 both groups were given the virulent anthrax bacteria. On the afternoon of June 2, the crowd, composed of farmers, veterinarians, physicians, journalists and scientists from near and far met to learn whether Pasteur was a dreamer or a prophet. What they saw was one of the most spectacular scenes in the history of peaceful science, a scene which Pasteur afterwards declared "amazed the assembly." Scattered about the enclosure, dead or dying, were the unprotected sheep. Twenty-two were dead; the other three survived only a short time. The vaccinated sheep were in perfect health. Thus was registered a victory of far-reaching importance in the conflict man is waging against disease.

This accomplished, he turned his attention to hydrophobia, that dreaded disease with a mortality of practically 100 per cent. and after years of careful, arduous labor, he prepared a vaccine which cut the mortality to less than 1 per cent.

For centuries some of the most fertile areas of the new world were uninhabitable to the white race, or if perchance any of this race settled in those regions, the appearance of yellow fever forcefully reminded them that they must move or die. Ninety times it invaded the United States, often enacting scenes which were the counterpart of the plague days in London. For four centuries the narrow Isthmus of Panama was regarded as the white man's grave. It is claimed that the first railroad constructed across it cost a human life for each tie. Ferdinand de Lesseps, who undertook to construct a canal across the isthmus, was forced to abandon it, not through lack of engineering skill, but because he did not recognize the part played by the mosquito. His men died like flies. Common laborers, nurses, doctors and engineers alike fell prey. One vessel brought over from France eighteen young engineers. Within a month after their arrival, all but one had died. Before the work was finally

abandoned, thousands had lost their lives, and it was hard to keep enough well to care for the sick. Eighteen per cent. of all the men employed had died and many more were helpless. Twenty years later, due to the advancement of sanitary science, a canal was constructed and that with a mortality of slightly less than 16 per thousand! To-day the mortality is less in the canal zone than in many of our large cities. The cause is due to the discovery of the cause and method for control of yellow fever.

The discovery of antitoxin for diphtheria has reduced the mortality of this disease from 30 to less than 3 per cent. and the introduction of the toxin and antitoxin foreshadows its absolute control. The work of the Dicks bespeaks a similar victory over scarlet fever. Typhoid fever is all but controlled. Asiatic cholera and plague are fast being swept from the earth. Typhus fever and a number of other diseases are within the control of man. What are the methods by which man is accomplishing such marvels? They are based on five firmly established principles:

(1) The so-called communicable diseases are caused by micro-organisms which are the descendants of other similar micro-organisms. If these disease-producing micro-organisms are kept away from the body of man there can not develop within him an infectious disease, regardless of his physical condition. These micro-organisms always breed true, and it is just as possible to grow a crop of diphtheria germs, typhoid germs or tuberculosis germs as it is to raise a crop of potatoes; and the bacteriologist would be just as surprised to reap a crop of diphtheria where he planted typhoid as the farmer would be to harvest potatoes where he had planted corn.

(2) The great majority of microbes which produce disease in man multiply only in the body of man and lower animals; hence, when seeking the disease-producing micro-organisms for laboratory study, we turn to man and the things which he has handled.

The evidence is complete that the microbes which cause tuberculosis, pneumonia, influenza, cerebro-spinal meningitis, scarlet fever, typhus fever, smallpox, whooping-cough, gonorrhea, syphilis, malaria, yellow fever and sleeping sickness multiply only in the bodies of animals. It is also an established fact that the number reaching the body of the animal is no larger than the number that leaves the body of another animal. Consequently, the idea that disease breeds in filth is only a myth.

(3) Diseases are transmitted through direct contact or through the intervention of flies or food. In other words, the principal spreaders of disease are fingers, flies and food. Numerous disease-producing bacteria are found in the mouth of the ill and often apparently healthy individuals, and it is a matter of little difficulty for those organisms to journey from the lips of one individual to the lips of another. The ordinary drinking cup is only one of the hundred and one things which come in contact with the mouths of many individuals every day and serves as the means of transportation. Hence, the idea that diseases are transmitted in the air was disproved when it was found that smallpox, measles or even scarlet fever can be housed in the same hospital, or even in the same wards with other patients without danger of cross infection, provided the necessary precautions are taken to prevent the carrying of infection from one individual to another by the attendants. Even malaria, yellow fever and the bubonic plague, which seemed to settle from the air on whole cities at a time, are now known to be conveyed by insects, and not by air; and it was the conclusion of

the Influenza Commission, after its careful study of the great influenza epidemic which so rapidly spread over all quarters of the globe, that this disease also travels in a "pair of shoes" and not in the air.

(4) A high state of bodily health should be the aim of all, but it does not necessarily confer immunity to the communicable diseases. We should laugh to scorn the individual who to-day would advocate keeping in the prime of condition so that he might resist the bullets of the enemy. Yet, how many believe that general good health protects against infection? We need only use our eyes to become aware of the fact that the physically fit and robust fall prey to typhoid fever, smallpox, influenza and most other infectious diseases as well as the weaklings. One should keep in the best of physical condition, for it is not until then that life is really made worth living, but every one should learn that disease-producing organisms must be kept away from his body if he wishes to avoid infection.

(5) In some diseases, immunity may be acquired by a mild attack of the disease produced by vaccination; in others it may be transferred from one animal to another through the blood by means of so-called antitoxins. Smallpox used to be one of the most dreaded diseases; to-day it has disappeared from the properly vaccinated community. Typhoid used to be the great scourge of the military and often civil authorities, but it has disappeared from the army and navy and is so rare in large cities that it is not uncommon to find young doctors who have not seen a case of typhoid. Properly used antitoxins reduce the death-rate for tetanus and diphtheria from 30 to 70 per cent. to almost the vanishing point.

EUROPEAN AND AMERICAN POLICIES IN THE PACIFIC COLONIES

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THE traveler comes away from French Oceanie with most vivid pictures of vast precipices, towering monoliths, flashing lagoons, and the sweep of great waves and pounding surf upon dazzling coral reefs set in sapphire.

But there are less pleasant impressions, too, chief of them a brooding atmosphere of decay, flavored with tragedy.

One observes the pitiful remnants of native peoples on islands that once teemed with tens of thousands; the deadening influence of French bureaucracy in world-distant Paris on these far-away mystic isles; and the corroding effect of European influences (often good in themselves) when applied blindly to people whose attitude toward life and society was so altogether different. The natives were destroyed long ago, and those in power to-day must not be blamed for the errors of the past.

However, the highly centralized government of France necessitates that any important decision must be referred to Paris, where some stupid or indifferent clerk may pigeonhole documents or give decisions on matters of which he can not possibly form any adequate conception. Governors are changed far too often to secure well-planned results, and even when a governor is well informed and zealous to remedy affairs he is sadly hampered.

Fiji is an English crown colony, with a population nearly equally divided between the indigenous black-skinned Fijians of magnificent physique and equally black-skinned Hindus of altogether different physiognomy and build. At the present time it is believed that the melting away of the native Fijians has been checked and that they are now holding their own in numbers, with a prospect that they may gradually increase. If this comes to pass, and the Fijians are given a chance to gradually develop new industries and improve the old, the English rule of to-day will well justify itself.

At Suva I talked with a British sea captain who had just returned from a long visit to the Hawaiian Islands. He contrasted the energy and development observed at Honolulu with the inertia, indifference and economic backwardness of Fiji. According to him part of this was due to English conservatism, part to short-sighted colonial policies, and part to the jealous restrictions imposed by Australia. For example, a promising fruit industry had been ruined by Australian regulations designed to freeze Fijian growers out of their only market.

West and northwest of Fiji lie the New Hebrides, a group of large islands extending northward for several hundred miles. The natives are Melanesians, naked blacks who still practice cannibalism upon the larger islands. Secure in their densely forested mountains, they have been able to maintain themselves fairly well in the past by eliminating (and often assimilating) those who invaded their islands. However, the past few decades have witnessed a great diminution in their numbers.

The English have always admitted that they are the world's premier colonial administrators. To those who

accept all such statements at face value it might be an eye-opener to visit the New Hebrides. The islands are administered under a strange governmental hybrid known as the Condominium, a joint arrangement in which both England and France share equally. Each country has a high commissioner and an equal number of deputies and native police. These officials are empowered to look after their own nationals only, to guard their interests and to protect the natives.

The New Hebrides are comparatively near the important French colony of New Caledonia, and French influence has always been strong in the islands. The way the Condominium has worked, British influence has waned and French prestige and strength have steadily grown stronger. Largely through the short-sighted jealousy and rabid racial prejudices of the Australians, British planters have been forced to sell out to French interests, until now nearly everything is in the hands of the French or those who have taken out French citizenship papers. For instance, on Segonde Channel only three English planters are now left where some years ago it was almost entirely in English hands.

Because of the Australian attitude English planters are not allowed to bring in outside labor from other parts of the British Empire, but are only allowed to recruit labor from the native blacks of the New Hebrides. For the most part the cannibals of Malekula, Santo and other islands are not enthusiastic about plantation labor and the planters are therefore usually shorthanded.

The French planters are allowed to bring in any French subjects, and therefore they bring in as many Anamese as needful. Of course the strictest supervision is exercised over the health, housing, sanitation, food and working conditions of these Anamese laborers, who are not only far better off than in their native land but are also better housed and cared for than most of the New Hebrideans working on British plantations.

Further north and slanting still more to the northwest lie the Solomons, a group of large islands stretching away for seven or eight hundred miles toward the equator. Most of the islands are colonies of Australia, but those at the north formerly belonging to Germany, Buka Buka and the great island of Bougainville, are governed by Australia under a mandate from the League of Nations.

The natives are Melanesians like those of the New Hebrides and have been long noted cannibals and head-hunters. The head-hunting voyages of the past have been stopped, but in the interior of Malaita, Choiseul and Bougainville life has changed but little from the days of old. These great densely forested islands have been very little explored and their lofty volcanic peaks, clothed with almost impenetrable jungle, have never been scaled.

Former German New Guinea includes not only the northeast quarter of New Guinea (the world's largest island), but also the Bismarck Archipelago, the Admiralty Islands, and Buka Buka and Bougainville of the Solomons. All this vast territory is held by Australia under a mandate from the League of Nations.

The people of this territory are blacks, Papuans and Melanesians, living much as those of the New Hebrides and Solomons. In the interior of New Guinea cannibalism and head-hunting are still rife.

The natives of the Solomons fall naturally into two groups: (a) the salt water natives, living on islets along the coast and nominally or actually christianized, and (b) the bush natives, who

preserve the old-time ways and are either slightly or not at all influenced by the white man.

Let us see what the government is doing for the natives of the Solomons. There is a commissioner at Tulagi, and a few hard-working magistrates scattered along the coasts of these great island wildernesses. Each magistrate has a small detachment of native constabulary.

Each magistrate controls a small area about his post; the salt water natives of course, and perhaps also for a distance of ten or twelve miles back from the shore in some places, more or less in others. Within the sphere of their influence these magistrates keep order, punish crime, and are hard-working men making the best of a difficult situation. But when home politicians urge the impossible there follow such things as the massacre of the local magistrate, his cadet and fifteen native police in Malaita near Auki.

One of their chief duties is to collect a preposterous head tax of ten shillings, which the Australian government levies upon each man.

But the government does nothing to develop trade in forest products such as rattan, gums and resins, or other resources of the islands, or to improve the native agriculture or mode of living.

When I asked "How do you expect these naked savages to pay such an outrageous tax?" I was blandly told, "Why, that is perfectly easy! All they have to do is go work on a plantation."

In other words the government head tax is a device for compelling the natives to work on plantations. It would not do to develop any native trade in forest products or otherwise make them financially self sufficient.

I do not mean to imply that this has all been worked out consciously or maliciously. To a large degree this policy is due to sheer stupidity and ignorance. Both in the Solomons and New Guinea various planters and government officials alike were amazed when I brought up the matter of trading in rattan, copal and other products. "Why, would anybody buy rattan?" was the reply I got over and over.

Rabaul, on the large island of New Britain, was the capital of German New Guinea, and is the capital of the Australian mandated territory. In the vicinity of Rabaul one gains an insight into the results of the German policies as contrasted to those of Australia.

"These natives around Rabaul are all too rich; they'll not work for any one" was what I heard several times.

Why do the Australians call them too rich, and where did they acquire their riches?

The German administrators were highly trained men of vision whose gaze encompassed the future. At their settlements permanent public buildings, docks and roads were constructed and everything prepared for development of the country and its resources. Each native householder was compelled to plant a few coconuts each year upon his own land, and each village was required to construct a certain section of permanent road. These were often high-handed measures.

Sixteen years ago the war gave the Australians a chance to grab German New Guinea, but the natives in the Rabaul region have copra to sell. This gives them money for cloth, knives and other tools, kerosene, tobacco and for their head tax. The roads unwillingly built under German rule give them easy communication. Their gardens and the sea supply them with most of their living. They are "too rich" to work for others.

All the public improvements and development in the New Guinea mandated territory date back to the Germans.

The planters of New Britain and adjacent islands get most of their labor from the mainland of New Guinea, particularly along the Sepik River and some of its tributaries. They ascend the Sepik for a hundred and fifty miles or more in search of recruits.

About a hundred miles up the Sepik I met a cultured young Englishman who put the situation well. He said: "These people do not need us at all. They are perfectly independent of the outside world and are better off without us, but we can't get along without them."

Everywhere in New Guinea one sees a wealth of rattan and other forest products utilized by the natives but otherwise untouched. As the people have nothing to sell, every able-bodied man and boy is compelled to contract with some planter to get tax money. The result is that in many villages there are only women and girls, old men and young boys; every lad over fourteen or fifteen and every able-bodied man has left. Accordingly the native life decays, the old laws fail, and nothing effective has been introduced to take the place of the old culture.

As positive accomplishments in New Guinea we may list the following: Suppression of head-hunting and cannibalism along the sea coast and for about two hundred miles along the banks of the Sepik River; suppression of the trade in crowned pigeon crests and bird of paradise plumes, thus preventing the rapid extinction of these birds of wondrous beauty; better control of labor recruiting and elimination of its most glaring evils; establishment of a school at Rabaul where Papuan boys are trained as plumbers, carpenters and the like. These boys are in demand on plantations, where they receive a pound a month and are the aristocrats of native labor.

Against these we may place the lack of vision to encompass a future for the natives other than as plantation hands; failure to work out a plan for improving the standards of living and economic status of the natives by bringing in new food plants or improved varieties of old ones; failure to provide a system of agricultural education for the natives; failure to lead the natives to the commercial utilization of forest resources; failure to develop transportation facilities; and lastly, a fault only too evident in our own country, too much political pull in certain government appointments.

When one enters Dutch New Guinea he encounters an altogether different atmosphere. Little coasting vessels creep into every inlet and from every village draw a store of rattan, copal, dyes, parrots, curios, button shells and other forest and sea products. These are forwarded to Makassar, Batavia and Singapore to be utilized there or sent on to other countries.

Instead of a head tax of ten shillings, the Dutch tax is two guilders, or eighty cents of our money. Furthermore, the assistant resident said that where there was little to sell as yet or for various reasons times were bad, the tax was reduced or even waived altogether. In recently organized villages, or where the wild people of the interior were just coming under governmental influence and as yet unused to the new ways, no attempt at all was made to collect a head tax.

West from Papua stretches three thousand miles of Dutch territory inhabited by Malays, heirs of an ancient culture in regions like Java, Bali, and parts of Sumatra and Borneo, still savage in the interior of Borneo and portions of other great islands.

The colonial work of the Dutch among these people is of course well known and dates back for centuries, when they wrested this rich region from

the Portuguese. The Dutch policies have undergone great liberalizing during the past few years, and the welfare of the native peoples is cared for by a body of extraordinarily well-trained, competent and devoted civil servants.

It is the policy to retain the land for the natives, improve their economic status, give them a certain amount of academic education in the vernacular, and look after public health and the interests of the natives generally, while encouraging the investment of foreign capital, the development of plantations and the introduction of new industries. Higher education is also provided for the wealthy and for brilliant students able to profit by it.

British North Borneo is a rather unique colony in that it is owned and governed by a private company. There is a scanty native population along the coast, and the rest of the natives live, for the most part, a long way inland. In consequence the government has encouraged the immigration of Chinese, mostly Hakkas, so that the capital, Sandakan, is almost a Chinese town.

The governor is a man of ideals and vision, and he and his staff, freed from the incubus of satisfying home politicians, are able to plan and work in such a way as to safeguard the landholdings and future of the natives. Conditions are therefore far superior to those in the colonies and mandated territory under Australia.

The difficult problems constantly arising in the administration of agricultural lands, forestry, relations of the various native groups with one another and with the whites and Chinese, are studied and acted upon with great care so that admirable progress has been made along these lines.

Not much can be said for the development of roads and land transportation, or of education. The fact that a considerable number of Filipinos are employed by the government of British North Borneo, along with a scattering of Hindus and an occasional Chinese, with a few whites in the key positions, is sufficient commentary upon the status of education in the colony.

In the Philippines we again enter islands where the native population has been in contact with higher cultures for many centuries, and where by far the greater part of the population has assimilated more of European culture than any other people of the tropics. The Spanish christianized the great bulk of the people, and in many ways brought them to a higher level than the other Malays.

After centuries of Spanish rule, the Americans stormed the "Pearl of the Orient" and proceeded to do things never before attempted in the tropical possessions of any European power. Mass education of all children, not alone those of the aristocrat but of the farm laborer, fisherman, Mohammedan and pagan, was begun. Many new things were introduced, such as public hygiene and sanitation, good roads, pure water supplies, sewers and docks.

Errors, blunders and stupidities there were in plenty, some comical or ridiculous, others pitiful or even shameful. But in spite of all mistakes both of omission and commission, the fact remains that as a result of policies begun under American control, encouraged by Filipinos like the late Dr. Pardo de Tavera, and in many cases ably continued by Filipinos trained in the United States, general conditions in the Philippines are superior to those in any other region of the tropical Pacific. The general level of education is far higher than in any of the other regions mentioned here, and the desire for education and cultural progress is nation wide in the Philippines.

No one is better aware than the writer of the shortcomings of the past thirty

years in the Philippines, and no one has been a severer critic of certain features of the policies pursued and their harmful effects upon both Filipino and American welfare. In spite of this I feel certain that no student of economic and political conditions can visit a series of tropical colonies and compare their status with the results attained in the Philippines and not recognize at once the superiority of the latter and the higher level of the Filipinos.

It would be futile to point out here mistakes made by both American and Filipino leaders, which a larger vision would have shown to be detrimental to the ultimate welfare of the great mass of people concerned. I shall merely state that the higher cultural and educational level attained by Filipinos in general places them in a different class from the natives of any of the colonies here considered. The fact that Filipinos are called upon to take over responsible work in government offices in various colonies outside the Philippines is sufficient to prove the statement. The fact that in the Philippines practically all governmental activities are conducted by Filipinos is not only a testimonial to their ability but is also ample justification of the general idea underlying American policies and of American faith in the Philippine people.

Every one conversant with conditions in the Philippines agrees that their present status can not be continued indefinitely. It is not just and fair to either Filipinos or Americans, whether their interests agree or diverge. Sooner or later Congress should decide the future of this wonderful group of islands, and in fairness to all concerned the sooner it is done the better. I, for one, am certain that many factors are slowly but surely paving the way to the complete independence of the Philippines. No matter what obstacles are placed in the way of this attainment and no matter how honest or sincere the opponents of independence may be, nothing can prevent its ultimate achievement.

PSYCHOLOGICAL ASPECTS OF CALENDAR REFORM

By Professor HOWARD C. WARREN
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In the efforts made to reform our lopsided calendar, too little consideration has been given to the principles of psychology. The popular mind clings to tradition in the fundamentals of life, as shown in our persistent cleaving to our bewildering system of weights and measures, and the British adherence to their inconvenient monetary system. It often requires a social cataclysm, like the French Revolution, to uproot these traditions.

An added difficulty arises in the case of calendar reform, due to religious doctrines and prejudices. In Christian, Jewish and Mohammedan countries the 7-day week, with its one day of rest, has been recognized from "time immemorial," and any attempted dislocation of this cycle inevitably meets violent opposition. The real problem, then, is how to overcome this popular inertia and religious protest.

Of the two proposed schemes, the 13-month year and the smoothened 12-month year, each has certain advantages. It is easier to associate day and date in the 13-month scheme, since these are the same in every month: the 7th always falls on Saturday—the 13th is always a Friday. In the 12-month calendar one has to remember three associations: in the Swiss calendar, for instance, the 1st of the month is Monday in January, Wednesday in February, Friday in March; Monday again in April, and so on—a very simple and easy reckoning compared with our present calendar, where no one but an expert can tell on what day the 12th of next October falls, or the date of Labor Day, or when school or college will open next year.

To those who receive weekly wages, 13 months of four weeks each seems preferable; while those on monthly schedules naturally prefer the 12-month division. For business and finance the latter has the advantage in reckoning quarterly and semi-annual earnings, in making quarterly dividend and semi-annual interest payments, and in making out and posting a lesser number of monthly bills. The four seasons fit better into the 12-month scheme too. An objection to the 12-month year is the thirty-first day that is added to one month in three, making the length of the months irregular. But this offers no real difficulty. According to the Swiss project, each quarter begins on a Monday; the third month with 31 days has five Sundays, so that it has the same number of work-days as the other months.[1]

Taken on its merits alone, the 12-month year works better. But even aside from this, it is preferable for psychological reasons. The community at large looks askance at a new month, as it does at a milligram and a kilometer. It will take an immense amount of pamphleteering and magazine-work to reconcile the public to such a drastic innovation. On the other hand, a mere rearrangement of length in the existing

[1] In the Swiss scheme the months of each quarter are given 30, 30, 31 days. In the World Calendar they are arranged 31, 30, 30, but the number of working days is the same in each month, since the 1st of January is Sunday. My preference for the Swiss plan is largely for historical reasons.

months should meet with comparatively little opposition, when the many advantages of this evening-up are pointed out.

The main obstacle to calendar reform comes from the 365th day, which throws the weekly sequence out of gear. Either one must begin each successive year on a new day, or else one must somehow "take a day off" every year—and two days off every fourth year. Here the reformer runs up against an even more powerful psychological factor: there is not merely passive inertia but active opposition to the proposed change. If the 7-day week has been divinely ordained, what is man that he should dare disturb the sacred cycle?

The force of this objection, as a factor of folk and religious psychology, has undoubtedly been underestimated by the calendar reformers. The church—whether Christian, Jewish, or Mohammedan—is a powerful institution in our present-day civilization, and unless its influence can be enlisted in behalf of the movement, the reform has little chance of success. Certain prelates, as individuals, have or can be won over; but so far as I know the ecclesiastical authorities are loath to lend official support.

What antagonizes especially the religious sense of the community is the idea of a "day without a name"—a *blank* day inserted, say, between Saturday and Sunday, which lengthens one week every year to an 8-day cycle. Does not this fly in the face of divine ordinance as well as of age-long custom? Is there any possible way of getting around this impasse?

For many years the calendar and its eccentricities fascinated me. In the 1890s I devised a simple mnemonic formula for calculating the day of the week for any date, past or future, on the Gregorian system. Later, I constructed a fairly simple universal calendar with circular disks, which could be set for any year and month. The scheme of calendar reform proposed in 1900 by L. A. Grosclaude[2] struck me as rational and feasible, apart from the ecclesiastical objection, whose importance was obvious to a psychologist. Some several years later a possible way of meeting this objection occurred to me. Instead of having a *blank* Year-Day, each year, why not give it a name? If the new calendar were put into operation, say, in 1932, let us call the Year-Day of that year *Year-Sunday;* the next year (1933) the Year-Day is called *Year-Monday*, and so on. Thus at the end of every seven years we have a *week* of Year-Days, which follows, at least in principle, the traditional 7-day cycle. And the same may be done with the Leap-Days. If Leap-Day in 1932 is designated as Leap-Sunday, then Leap-Day in 1936 is Leap-Monday, and so on—again a 7-day cycle.

Such was the device that occurred to me as a means of overcoming religious scruples. It follows the main plan of the Swiss (Grosclaude) calendar—an ideal system for reckoning weeks, months, and days—and at the same time it preserves the weekly cycle, though in a novel way. My plan was described in a *Science*[3] article published during the World War. At that time many of us expected that a notable social reorganization would result from the war; and to me at least the time seemed ripe for calendar reform. But, here again, the psychological factor was not sufficiently taken into account. I had no leisure to start systematic propaganda; the *Science* article, the numerous offprints which were sent out, and desultory personal efforts by the author, failed to enlist a vigorous champion of this plan. When interest in calendar

[2] See *Revue Scientifique*, 1900, 4ᵉS., vol. 13, p. 766.

[3] "A Common-Sense Calendar," *Science*, n. s., 47: 375–377, 1918.

reform revived it followed other directions. Why? Because those other systems had active promoters, who carried on the campaign along carefully prepared, strategic lines. This is excellent "psychology."

The reader will note an apparent contradiction here. I started out by suggesting that the advocates of calendar reform were rather blind to the principles of human psychology. And now they are commended for using good methods of applied psychology. But the contradiction is only apparent. It is one thing to excite attention—quite another thing to induce acceptance; for attention may produce opposition instead of conviction. Unless the arguments for reform are so powerful as to sweep aside such opposition, the movement is bound to fail.

The psychologist would urge the reformers, first of all, to present a united front. Let them agree on either the 12-month or the 13-month calendar. But let them *unite*. An equally important step is to enlist the active support of ecclesiastical authorities in the leading religions and sects; for their influence counts more than any other single factor. The industrial and financial leaders too must be enlisted—not merely as supporters but as active workers. And our educational leaders should be brought into the fold—for what school or university or professional institution is not vexed by the wanderings of the "academic year"?

The ecclesiastical authorities will be hardest to reach. It is true that the present calendar bears the name of a distinguished pontiff. But his reform involved only a slight dislocation of the Julian calendar. The church will not readily accept a change which involves altering many feast-days, fasts and saints-days. The tremendous value of the new system must be made clear beyond peradventure. I am inclined to doubt whether this can be done without adopting the device of the Year-Week and the Leap-Week, with its compensatory Year-Sunday and Leap-Sunday, which round out the age-long 7-day cycle. Even this may not meet the prejudices of certain strict constructionists. But all others can be brought into the fold if the advantages of the change are made evident. For "the Sabbath was made for man—not man for the Sabbath."

To sum up: It is not sufficient to agitate for reform. The appeal must be made to this, that and the other individual and class of society. There are abundant arguments for calendar reform, one or another of which should strike home to almost every group in the community. The best strategy is to attack each group or class with those particular aspects of the reform which will affect and improve their own situation.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

HOW INSECTS AFFECT OUR HEALTH AND COMFORT

By F. C. BISHOPP

BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE

INSECTS are man's most relentless foes. They oppose him as he struggles to release a few acres of farm land from the grasp of the wilderness on the frontiers of civilization. They attack him with deadly effectiveness as he enters the unexplored jungles of the tropics in pursuit of gold or game. They greet him with their million vicious stings as he tramps the tundra of the great Arctic region. They contest his rights to live peacefully by the tilling of the soil in the fertile valleys and plains of the world. Even in the great cities where man appears to have thoroughly conquered nature, the persistent army of insect foes devours his foodstuffs, eats holes in his Sunday-go-to-meeting clothes, accompanies him to his work in the seams of his garments, or sallies forth at night from his mattress or flies through his unguarded window to satisfy gluttonous appetites on his very life blood.

In the meantime the trench diggers of the insect army are mining beneath his garden and stealing the products of his toil, while others far from the habitations of man tunnel and kill his great forest trees. Even the timbers of his house crumble under the attack of the hidden hordes. In true war-time fashion, one division of the army strikes at his lines of communication by weakening the telegraph and telephone poles, while another actually burrows through the lead cables and throws whole systems of communication into chaos. With all the millions of dollars of loss caused by our innumerable insect foes, I would not have you think that all bugs are bad bugs. We all remember our indebtedness to the honeybee and the silkworm, but we may forget the vital part which insects play in helping us to produce our fruit and other crops by fertilizing the flowers and in directly attacking and destroying countless numbers of destructive hordes. This interesting and important rôle of the deserters and revolutionists in the insect army is well illustrated by the oft-repeated ditty:

> Little fleas that do us tease
> Have other fleas that bite 'em,
> And these in turn have other fleas,
> And so *ad infinitum*.

When each of you comes to understand more fully the size and might of the insect army, the thousand and one ways in which this army is recruited, its diverse and subtle methods of attack and the intricate defenses which nature has thrown up to protect some of her works from the destructive forces of others, you will see more clearly the need which man has for a considerable number of workers to study the strategy of the invaders and to forge effective weapons of defense. One of the largest and best trained and organized armies ever developed to oppose these insect invaders is now on the firing line in the Bureau of Entomology of the United States Department of Agriculture and in the entomological units of the various state experiment stations and other

state organizations. And the U. S. Public Health Service gallantly occupies certain sectors of the front, especially in offensive operations against mosquitoes. One of the eleven divisions of the Federal army of entomologists of the Department of Agriculture is directing its efforts against the insect foes which directly affect man and his flocks and herds. The tactics and types of troops employed by the enemy cohorts with which this division of the bureau is engaged are extremely varied. Some, like the house fly, pick up and put on the food and in the milk such dangerous germs as those of typhoid, dysentery and tuberculosis. Others, such as the mosquitoes whose surname is Anopheles, serve as incubators for the malaria organisms and without these mosquitoes this disease could not survive or spread. Certain diseases are introduced into the blood of man or domestic animals by the bite of a bug or tick, while the germs of others may be deposited on the skin while the insect is feeding and then gain entrance to the body through a puncture made by an insect or through injuries made by scratching. Some insects harbor the young of dangerous parasitic worms which find their way into man or animals through the bites of these insects or through the visitation of open wounds by them. Sometimes a bird or other animal will eat these worm-infested insects and thus itself become infested.

Many of the insect army are not given to carrying diseases but sally forth with lance-like beaks or poisonous stings. Others of the army refuse to fight in the open, but invade the skin of man and his faithful animal friends and make life intolerable by the persistent itching which they cause. There are biters whose juices blister the skin; caterpillars with hairs more venomous than the fangs of the rattler; wasps and bees with vicious stings; blood-sucking flies with beaks like a hot needle. Then there is the almost omnipresent maddening hum of mosquitoes large and small punctuated by their stinging bites. The dainty but heartily cursed sand fly, which mocks the mosquito hovering outside the screen, climbs nimbly through its meshes and indulges its appetite on the infant's dainty blood. Nor will the elusive flea forego his desire to keep in the spotlight of our attention, though we have largely relegated the disgusting cootie to the poorer and more crowded quarters of our towns and cities and to the unfortunates who inhabit these places. In the meantime the eight-legged relatives of the insect hordes, the irritating chiggers and ticks, would by united attack drive us from our favorite woodland haunts and grassy dells. Again, the enemy, in the guise of flies with brilliant green uniforms, lays eggs on wounds and the resulting maggots cause disfigurement or death by their gnawing.

And speaking of this group of scavenger flies, here is a very remarkable and interesting thing. Since the war Dr. W. S. Baer, of Johns Hopkins University, has found that the young or maggots of the flies can be made to work for us in a way that promises to be of untold help to suffering humanity. In hospitals and elsewhere the surgeons are beginning to use them to clean up the diseased material in certain grave bone troubles and to stimulate normal healing.

The outcome of the battle against the multitudes of hostile insect warriors lies largely with you. After all, the entomologist is only the sentinel on guard, the scout to find where the enemy lurks, the strategist to determine the weak places in the army's defense and to map out the plans for breaking down its offensive: the directing officer to assemble the opposing army and the munitions of war. But you, the household-

ers and farmers and manufacturers, make up the rank and file of this army and must do the fighting if victory against the insect host is to be won.

When the foe is a new invader the government and state forces, by concentrating all efforts on complete extermination, as in the case of the recent battle so decisively won against the Mediterranean fruit fly, may with your support and cooperation carry the day. But extermination is neither practical nor possible in most cases. These foes must be met on a hundred fields of action day after day—year after year. Many of the plans of defense are not yet well worked out by the entomologist; the problems are formidable, their solution is difficult, and your patience and support are craved. The tactics of many divisions of the invading army, however, are now well known and the plans of offense well worked out. Some of these call for you to enter the trenches and smoke the enemy out and thus forestall his offensive. In fact this is the strategy which must be employed against many of our foes. To succeed in economical production of live-stock, dairy products and poultry, to reduce to a minimum the dangers of insect-borne diseases, to avoid annoyances due to pestiferous insects, you should know your enemies—know your bugs. The Bureau of Entomology is ready to prepare you for a successful combat against many of those pests which worry your live-stock, reduce your income and interfere with your comfort and happiness.

SEA BEACHES AND THE TIDE

By Captain PAUL C. WHITNEY

CHIEF, DIVISION OF TIDES AND CURRENTS, COAST AND GEODETIC SURVEY

THAT so many people select the sea beaches for their favorite summer vacation retreat may have an origin in the geological past when we, as denizens of the deep for countless generations, lived and died between the tidal levels and in the shallow warm waters of the ancient seas. Thus our present love for the ocean may result from a slight homing instinct carried down through the ages.

The beach is nature's perpetual battlefield where relentless war between land and sea is waged without truce, and where either side may gain or lose according to local circumstances. It is always a source of delightful new experiences. Each day we can make a new find or observe something of nature that opens new vistas of our wonderful world. At high tide or at low tide, after a storm or even during calm weather there is a new shell to pick up or a bit of drift, around which to weave a story. Its fresh salt air acts as a tonic after months spent indoors, and a few days' communion with the sea is good for us, both spiritually and physically.

There are several types of sea beaches. The sand beach is usually the mecca of the summer tourist and is of course the only beach where ocean bathing can be thoroughly enjoyed. To those of us who enjoy nature and the many manifestations of her handiwork, the sand beach has many interests other than of bathing and the latest styles. The booming surf, bringing its message of distant storms, is of constant interest and never twice alike. The destructive power of the breakers can be seen any time during one of the heavy northeasters that occasionally visits our eastern coast. These storms are generally accompanied by unusually high tides and are awe-inspiring in the extreme. The constant play of the surf day after day, year after

year, finally works the largest rock debris into the fine grains of sand that are a part of the present beach.

Some sand beaches pack smoother and harder than others, and the shape and composition of the sand grains that make up each beach have a great deal to do with this condition. Daytona Beach, Florida, where all the fast automobile records are made, is perhaps the finest example of a smooth, hard beach. The advantage of such beaches over man-made roads for speed trials is that no matter how smooth the road was originally, time and traffic are bound to leave their mark; as for the sand beaches, each flood tide recreates their original smooth surface.

There are many forms of life present on a sand beach at low water and if any one has an idea that a crab is slow, let him try to catch a fiddler crab before he darts into his sand hole. The lace-like jelly-fish, in some places known as the sea nettle, a beautiful creature when drifting around in his own environment, is not a thing of beauty when thrown upon a beach and left by some retreating wave. With no supporting bony structure of any kind, the jelly-fish is so low in the scale of life that it even looks up to the lowly earthworm. Nor does it suggest as a mass of red or clear jelly its special stinging defence that many a bather has experienced when in contact with one.

The clam is another inhabitant of the sandy beach, and the pure white shell of some New England clams was the reason for the old belief that "they fed only on white sand." The picturesque clam digger as he solitarily bends over his labor has been described by many writers. The sand clam is dug during low tide and at this time its presence is sometimes indicated by a spout of water as one walks nearby. The razor clam is long, narrow and sharp on the edges and is able to descend in the sand so fast that one must dig quite rapidly to catch him. As the clam feeds during high water and then is also safe from the clam digger, the old saying, "as happy as a clam at high tide," probably is true.

The searcher may some day be rewarded by finding a piece of ambergris, that tallow-like substance supposed to be formed as the result of a disease of the sperm whale and when cast out by the animals floats on the surface of the water until thrown ashore on some beach. It is used in the compounding of perfumes. Masses of over 100 pounds have been found and as it is worth many dollars an ounce, a find of a large piece means a fortune to the lucky finder.

And the rocky beach, hard to walk along, but of greater fascination, perhaps, than the sand beach. Here we find rocky cliffs being eroded by the tremendous cutting and undermining powers of the surf breaking at their bases, and the debris from this losing battle strewn about in various shapes and sizes. On the rocks, uncovered during the lower tides, we find mussels growing in great quantities; and the tiny shellfish, known as the periwinkle, good to eat when boiled and you are very hungry; or the five-pointed starfish, one of nature's early experiments in evolution and perhaps the forerunner of our five-fingered hands. Children like to dry them out and take them home where they finally find their way to the attic along with the old family album. The sea-urchin, another curious product of nature's workshop, has a ball-shaped shell, covered with spines. Sea-urchins are not appetizing-looking, but the sea-gulls apparently know better as they carry them from their rocky homes to lofty heights and drop them to break their shells. These broken shells are not uncommon on the beaches. Frequently whole dried shells are cast up and their dome-shaped symmetrical outlines are very pleasing.

Another beach, but found only in the

southern waters, is the coral beach. This strand is composed of coral debris, of finely divided matter from the skeletons or limestone framework which serve to support the coral animals while they are living. Such beaches are gleaming white in the midday sun. Just outside of the low water fringe, an observer may see the protruding tops of living coral communities. These never attain a height above the plane of mean low tide and serve to maintain the large supply of material which is continually being ground up by the action of the waves. The skeletons of coral polyps are found in various shapes and their characteristic forms give rise to designating names, such as mushroom coral, fan coral, tree coral, bud coral, brain coral, etc. To get the full effect and beauty of growing coral, one must find a sheltered coral lagoon and in a boat on a calm bright day drift slowly over it. This undersea scenery is magnificent and a woodland glade is no more beautiful than the effect from the sun shining through the clear water, lighting up the various coral branches and shapes with the highly colored tropical fishes swimming lazily about.

One striking feature of the sea beach is the daily rise and fall of the water, known as the tide. The regularity of this ebb and flood was thought by the ancients to be caused by the breathing of some mighty animal supporting the earth. Our present knowledge tells us that it is the natural result of the tide-producing forces of sun and moon acting on the waters of the ocean. As the daily positions of these bodies are known in advance, their combined effects on the waters of the seas can be predicted. The mariner, as well as the yachtsman, the fisherman, the bather, the engineer and others, often desires to know in advance the state of the tide, and to supply this information the Coast and Geodetic Survey, through its division of tides and currents, annually publishes in advance tide tables that give daily predictions of the times and heights of high and low water along our coast as well as foreign ports. These predictions at one time involved long and laborious mathematical computations, but are now made on the survey's tide-predicting machine, a marvel of mechanical skill and mathematical ingenuity. Visitors to Washington are cordially invited to the Coast and Geodetic Survey where they can see this machine at work. Right now it is busy predicting the tide at Nagasaki, Japan, for the year 1933, where the tide has a rise and fall of about 5½ feet; but it predicts with equal ease the tide in Cook Inlet, where the range is 30 feet and more.

Giving advance information of the rise and fall of the tide is not the limit of this robot's ability. It also predicts the times and velocities of the tidal current and these are given to the public in the form of current tables, and like the tide tables are annually published in advance.

In closing, I wish to call special attention to the fact that although the tide and tidal currents can be predicted, there is that uncertain current in and just outside the breakers called the undertow of which there is little definite information. Its strength of flow is probably due chiefly to the angle the advancing wave-fronts make with the beach. This current, under certain conditions of surf and wind, transports large quantities of sand from one location to another along the coast, and, together with the waves that are produced, is probably the most important agency contributing now to shore-line changes. To the inexperienced swimmer this current is a grave hazard, and he must be careful to keep out of its influence or possibly be rapidly carried beyond his depth. Its neglect can be the cause of many drownings.

THE ROYAL SOCIETY OF LONDON AND ITS INFLUENCE UPON SCIENTIFIC THOUGHT IN THE AMERICAN COLONIES[1]

By FREDERICK E. BRASCH
CHIEF OF SMITHSONIAN DIVISION, LIBRARY OF CONGRESS

(Continued from the October issue)

In the further study of colonial scientific contribution to the Royal Society we now come upon one of the most interesting of men, namely, John Mitchell. The life of this scholar is devoid of the essential facts relating to his early life and education, but his later years are full of successful and manifold activities, of which he left abundant record. Mitchell was born in Scotland and was educated for the career of medicine, and came to the colonies about 1700 and settled in Virginia on the banks of the Rappahannock River in Urbana.

Mitchell's great interest in science is evidenced by his rich contributions to the study of electricity, botany, medicine, agriculture, history and cartography, a detailed account of which, however, would be beyond the capacity of this paper. After nearly fifty years of residence in the colonies, Mitchell returned to London, in 1746, and was made a member of the Royal Society by being elected a fellow on December 15, 1748. He never returned to the colonies, but died in London in 1768 of an illness which he had contracted in Virginia.

By virtue of his scientific training, Mitchell was eminently fitted for pioneer research work, as his powers of observation were keen and his deductions accepted by the leading scholars of Europe. Due to his skill he was able to make great botanical collections, and this material was highly appreciated by those to whom it was sent, as is evidenced by his voluminous correspondence with such scholars as Sir Hans Sloane (president of the Royal Society), Peter Collinson, Linnaeus, Gronovius and Dillenius.

Mitchell had early recognized the merits of Linnaeus' system of the classification of plants and had mastered its technical details, and it is to this fact that he owes a large measure of his success as a botanist. The first of his writings to be published of which there is any record is entitled "Dissertatio brevis de principiis Botanicum et zoologorum," written in 1738 and dedicated to Hans Sloane. This was followed in 1741 by another botanical paper, "Nova Plantarum Genera." These were offered for publication through that clearing house of botanists conducted by Peter Collinson in London. The second paper was dedicated to Collinson. In the latter publication Mitchell describes 30 new genera, of which twenty-four were proposed as new; nine certainly were original and have been confirmed as true genera by subsequent botanists. Two years before he went to London he visited John Bartram and Benjamin Franklin in Philadelphia. With the former he discussed botanical problems and with the latter the details of the infant science of electricity. Early in 1746 he sailed for England with more than a thousand specimens of native plants. Mitchell lost all his belongings, however, when the ship was captured by Spanish privateers, and it was not until many months later that his collection found its way back to him, but in a ruined condition, "to the great misfortune of

botany," as stated by Linnaeus. He attempted to renew his collection with fresh specimens and seeds sent him by Bartram, with whom he continually corresponded.

In 1744 he wrote a lengthy report on the epidemic of yellow fever which prevailed in Virginia in the years 1737, 1741 and 1743, giving his observations on the many cases which he treated. This paper was given to Benjamin Franklin to be presented before the new scientific society called Junto which Franklin had just formed in Philadelphia. As was the custom at that time, Mitchell's paper was referred to Dr. Cadwallader Colden, of Albany, for criticism. This report, together with Colden's letter of comment, came into the hands of Dr. Benjamin Rush some years later and formed the basis of his treatment of an outbreak of that disease which occurred in Philadelphia in 1793. This paper of Mitchell's was finally published in volume 4 of the *American Medical and Philosophical Register*.

Mitchell's first paper[27] to the Royal Society was in the form of a letter to Peter Collinson, from Urbana, Virginia, April 12, 1743, entitled: "An Essay upon the Causes of the different Colours of People in different Climates." This lengthy essay was demonstrated in seven propositions and is based mainly upon the philosophy of Sir Isaac Newton concerning the causes of color. It concerns the color of the white, black and yellow races, as he found them in the American colony. His essay on "An Account of the Preparation and Uses of the various Kinds of Pot-ash" followed and was read on November 17 and 24, 1748. In this paper[28] he enters into a discussion on the great economic value of potash and methods of preparation in vogue in the various countries of the world. His next communication to the Royal Society was a letter addressed to Dr. Birch, the secretary, "concerning the Force of electrical Cohesion." He also presented to the Royal Society one of Franklin's first papers which was entitled "Sameness of Lightning and Electricity." It was this paper which was laughed at by the "connoisseurs."

Chemistry seems to have attracted Mitchell's attention to some extent, for we find him writing to Bartram in 1747 for a "specimen of the water which turns iron to copper and the earth salts, etc., about it which I would analyze." There is no record, however, that he ever made this analysis.

From a letter to Bartram, dated August 1, 1750, it is apparent that he gave up his scientific studies for another form of livelihood. We find him writing about American affairs, on which, no doubt, he was an authority, based upon nearly fifty years of residence in the colony. He published a comprehensive work in two volumes, which was entitled "The English in America." In this work he dwelt at length on the agricultural practices of the colonists and a description of the natural products.

At the beginning of the hostilities which preceded the French and Indian Wars, Mitchell was employed by the home government to prepare a map and a report on the condition of the colonies. "The map which Dr. Mitchell made was issued in 1755. One hundred and seventy-one years later, in 1926, this map was twice laid before the Supreme Court of the United States of America and twice before the Law Lords of the British Privy Council. In the meantime many editions of Mitchell's map were published, many facsimiles of parts of it were made, and legal and historical arguments were repeatedly based upon its geographical features. Without serious doubt this is

[27] *Phil. Trans.*, R. S., 43: 102–150, 1744.
[28] *Ibid.*, 45: 541–563, 1748.

the most important map in American history."[29]

We now come to the most imposing and outstanding man of his time in the American colonies, namely, Benjamin Franklin, who follows next in order of election to fellowship in the Royal Society, having been elected in 1756. Franklin was born in Boston, January 17, 1706. He acquired some schooling there, but after a few years was set to work learning the printer's business, and from this time on his intellectual development was one of constant self-effort. At the age of 17 he moved to Philadelphia, where he resided and developed his many activities until his death in 1790.

Franklin was virtually the intellectual ambassador of his fellow beings at home. His remarkable services, both at home and abroad, were such that in either case his name would have made history. Also in any one of his scientific and practical attainments he contributed profoundly to the advancement of science in the colonies. During his residence in England he was extremely active in seeking privileges for his colleagues to present scientific papers before the Royal Society, securing for them memberships to academies, as well as honorary degrees from universities. He acted as agent in purchasing books and scientific instruments for the various individuals and colleges in the colonies. His associates at home were the leading scholars of the colony, namely, John Winthrop IV, of Harvard College, Ezra Stiles, of Yale College, Cadwallader Colden, of New York, James Madison, of William and Mary College, David Rittenhouse and John Bartram, of Philadelphia, as well as many others. Probably no man of his period had such a voluminous correspondence with so many of the prominent scholars on both sides of the Atlantic Ocean as did Franklin. The greater portion of this correspondence has been kept intact and is preserved in the Library of Congress.

In taking account of his contributions to science, some of Franklin's biographers enumerate them as covering twenty or more different fields of interest. It will not be possible within the limits of this paper to consider any but his major activities. It is known that he became vitally interested in science about 1743, when not quite forty years of age. However, much of his time was spent in attending to the public affairs of the colony in spite of his wish to devote his life to experimental sciences.

It was most natural that a man of Franklin's temperament would desire intellectual companionship, and this is expressed most fully in his attempt to form a society of ingenious men residing in the colonies. He knew of the success of the Royal Society of London, now over three quarters of a century in existence, and from this society he secured ideas of incorporation, membership, qualifications and other necessary details. Until this time the society had exerted great influence upon the intellectual and scientific life of the colonies. Its *Transactions* were to be found in the libraries of Harvard and Yale Colleges and in the homes of the leading scholars. The first intimation we have of the desire of Franklin to form a society is found in a circular letter dated Philadelphia, May 14, 1743, entitled "A Proposal for promoting useful knowledge among the British Plantations in America." The society was duly formed and existed for over twenty years, but in the year 1769 was merged with a rival society, and was then known as the American Philosophical Society, of which Franklin became the first president, which office he held until his

[29] Statement made by Dr. L. Martin, Chief, Maps Division, Library of Congress in a speech before the Am. Hist. Assoc., Dec. 30, 1927.

death. After the signing of the Treaty of Paris in 1783 the Royal Society gradually lost influence in the colonies and its former prestige enjoyed by the American Philosophical Society.

Much has been written regarding Franklin as an inventor, meteorologist, oceanographer, physicist, medical adviser and even as a mathematician and astronomer. However, it was through his great discoveries and contributions to electricity that he became known as a scientist. His first interest in the subject of electricity seems to have been aroused in the year 1746, when, on a visit to Boston, he attended a lecture said to have been given by a Dr. Spence, of Scotland. However, it is known that Professor Winthrop, of Harvard, was the first to give experimental lectures in electricity in the American colleges[30] (May 10, 1746) and being a close friend and correspondent of Franklin's, it is more than likely that he received his ideas from Winthrop. In 1745 Peter Collinson,[31] an English friend, sent to the Philadelphia Subscription Library with the necessary equipment a description of some electrical experiments which had been made in Germany. The following year, after his return from Boston, Franklin attempted similar experiments, and in 1747 and 1748 in a series of four letters to Collinson[32] he explains the ingenious attempts which he made to discover the properties of electrical fluid. From this time on his electrical discoveries followed in rapid succession. Franklin's first discovery was that copper or iron points had the power of drawing and throwing-off electrical matter when charged by lightning, which up to this time had not been observed by the European scientists. He also made the discovery of a plus and minus state of electrical charge, which are now known as positive and negative charges. From this principle he explained the phenomena of the Leyden jar.

He showed decisively that when the jar was charged it contained no more electricity than before, but that as much was taken from one side as was thrown on the other; and to discharge it nothing was necessary but to produce a communication between the two sides, by which the equilibrium might be restored, and that then no signs of electricity would remain. He afterwards demonstrated that the electricity did not reside in the coating, as had been supposed, but in the pores of the glass itself. After a jar was charged, he removed the coating, and found that upon applying a new coating the shock might still be received. In the year 1749, he first suggested his idea of explaining the phenomena of thunder and lightning and of the aurora borealis upon electrical principles. He points out many particulars in which lightning and electricity agree, as well as reasonings from facts, in support of his positions.

In the same year he conceived the astonishingly bold idea of ascertaining the truth of his doctrine, by actually drawing down the lightning, by means of sharp-pointed copper or iron rods, raised over buildings. Even in this uncertain state, his passion to be useful to mankind displayed itself in a powerful manner. Admitting the identity of electricity and lightning, and knowing the power of points in repelling bodies charged with electricity, and conducting imperceptibly their charge, he suggested the idea of securing houses, ships and trees from being damaged by lightning by erecting pointed rods, that should rise some feet above the elevated part, and descend some feet into the ground or the water. The effect of

[30] "Phil. Exp. Lecture," mss. note book, Treasury Room, Harvard University.

[31] James Brett, "Life of Peter Collinson."

[32] "Exp. and Obs. in Electricity made in Philadelphia." London, 1751.

these, he concluded, would be either to prevent a stroke by repelling the cloud beyond the striking distance, or by drawing off the electrical charge which it contained; or, if it could not effect this, it would at least conduct the electric charge to the earth, without injury to the building.

It was not until the summer of 1752 that he was enabled to complete his profound discovery by experiment. The plan which he had originally proposed was to erect on some high tower or other elevated place a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, according to his theory, conduct a portion of their electricity, which would be evidenced by sparks being emitted, when a key or other conductor was presented to it. Philadelphia at this time afforded no opportunity of trying this experiment. However, it occurred to Franklin that he might have more ready access to the region of clouds by means of a common kite. He prepared one by fastening two cross sticks to a silk handkerchief, which would not suffer from the rain, as would paper. To the upright stick was affixed an iron point. The string was, as usual, of hemp, except the lower end, which was of silk. Where the hempen string terminated, a key was fastened. With this apparatus he placed himself under a shed to avoid the rain and raised the kite; a thunder-cloud passed over it, but no sign of electricity appeared. He almost despaired of success, when suddenly he observed the loose fibers of his string to move towards an erect position. He now presented his knuckle to the key and received a strong spark. How great must his sensations have been at this moment! On this experiment depended the fate of his theory. If he succeeded, his name would rank high among those who had advanced science; if he failed, he must inevitably be subjected to the derisions of mankind. The anxiety with which he looked for the result of his experiment may be easily conceived. Doubts and despair had begun to prevail when the fact was ascertained in such a clear manner that even the most incredulous could no longer withhold their approval. Repeated sparks were drawn from the key, a jar was charged, a shock given and all the experiments made which are usually performed with electricity.

The far-reaching results of these experiments are only too evident in the practical developments of to-day. One specially outstanding field has developed which has been of profound importance, namely, the field of atmospheric electricity and terrestrial magnetism. Franklin's work was the direct inspiration of the very recent experiments made by two distinguished German physicists in harnessing the tremendous electrical potential of thunderstorms to a new type of x-ray tube.

The letters which he sent to Mr. Collinson, it is said, were refused a place in the *Transactions* of the Royal Society of London. However this may be, Collinson published them in a separate volume, under the title of "New Experiments and Observations on Electricity, made at Philadelphia, in America." This book went through five editions between 1751 and 1774, and has been translated into different languages.

Dr. Priestley, in his "History of Electricity," published in the year 1767, gives a full account of Franklin's experiments and discoveries. "Nothing was ever written upon the subject of electricity," he says, "which was more generally read and admired in all parts of Europe, than these letters."

The news of the brilliant discoveries of Franklin soon extended to Europe, and the world became aware of the fact that the American colonies had pro-

duced a scientist of the highest caliber, and after a hundred and eighty years the scientific world is returning at this time to the amazing generalizations made by Franklin. He was equally well qualified to construct theories as well as to perform experiments to test them. This is readily evidenced by any one of the papers on the many subjects upon which he wrote. We find eight papers published in the *Transactions* of the American Philosophical Society and eleven papers in the *Philosophical Transactions* of the Royal Society. In recognition of his many contributions to science he was honored by the Royal Society with the Copley medal in 1753 and elected fellow in 1756. In addition, he received honorary degrees from the colleges of Harvard, Yale, William and Mary and Pennsylvania. The universities of Edinburgh, Oxford and St. Andrews honored him with the degrees of doctor of laws and for his medical contributions he was elected a member of the Royal Society of Medicine, Paris, in 1776, and the Medical Society of London. At the age of eighty-four Benjamin Franklin died, the most honored man of his age, and lies buried with his wife in the Christ Church burying ground in Philadelphia.

From the study of the history and evolution of scientific thought in the colonies from 1636 until this time, we find that it has gradually been transformed to a higher level of authority, accuracy and refinement. Calvinism and Puritanism were gradually being forced to recede and become a part of the rationalism then permeating colonial life. This is embodied in the life and work of our next fellow of the Royal Society, John Winthrop, IV, who was the most profound scholar of the colony during the seventeenth and eighteenth centuries. Winthrop was the direct descendent of the Winthrops referred to earlier in this paper. We shall sketch his life briefly and analyze his contributions to early astronomy, seeking thus to justify his place in the history of science in America—as its first real scientific astronomer and Newtonian disciple. He was born in Boston, December 19, 1714, of parents already distinguished in the social and intellectual life of the community. He entered Harvard College at the early age of fourteen and immediately established his place as one of the first scholars of his class. His great fondness for mathematical studies and experimental science, combined with a temperament tending toward idealism, soon led him to contemplation of the stars and the laws governing their motions. After his graduation from college in 1732 with the degree of master of arts, he retired to his father's home and for the next six years very little was known of him. However, from two precious manuscript commonplace books now preserved at Harvard College we find evidences of private study which forecast his future work. These books reveal his wide general reading, and recorded observations of natural phenomena such as sun-spots, magnetic variations and meteors, mathematical problems and philosophical meditations. Upon the forced retirement of his own professor, Isaac Greenwood, there was a vacancy in the Hollis professorship. The overseers of the college had not far to look for a successor. John Winthrop was appointed, at the age of twenty-four years, to become full professor of mathematics and natural philosophy. He had been examined as to his proficiency in mathematics and the physical sciences, but the question of examining his religious statutes gave the authorities real concern. His views were suspected as being a little too broad for Harvard, even though his ideas embodying the spirit of the Lockean or English philosophy of em-

piricalism were just the force that Harvard needed. At any rate, he was accepted on the first examination and passed over on the second, and duly inaugurated to the office which he held for the next forty years with honor and distinction to Harvard and to the history of cultural progress in America. One of the most remarkable steps he took at the beginning of his professorship was to secure a copy of Newton's "Principia." At the age of twenty-five, we find Winthrop assiduously engaged in mastering the "Principia," which he so brilliantly applied to all his long years of subsequent work in astronomy and natural philosophy and in research and class instruction.

The modern laboratory was not known then, but Winthrop possessed apparatus which will illustrate the fundamental facts of natural philosophy then known. "For "Astronomy," he says, "we had before been supplied by Mr. Hollis with telescopes of different lengths, one of 24 feet; and a brass quadrant of two feet radius, carrying a telescope of greater length, which formerly belonged to the celebrated Dr. Halley. We had also the most useful instrument for dialing; and for surveying, a brass semi-circle, with plain sights, and magnetic needles. Also a curious telescope, with a complete apparatus for taking the difference of leveling. From a number of gentlemen of the province the following additions were received: a fine reflecting telescope of different power; microscopes of the several sorts now in use; Hadley quadrant, fitted in a new manner, a nice variation compass, and dipping needles with instruments for the several magnetical and electrical experiments."

From an original manuscript notebook in the library of Harvard College we find the first authentic astronomical observations made by Winthrop, dated April 19, 20, 21, 22, 1739, on sun-spots with an 8-foot telescope. There are several well-executed drawings, showing the positions, apparent movement and structure of the spots. He also made observations as to their physical character but does not enter upon any discussion as to the theory of their origin. He did recognize them, however, as an integral part of the sun and not something wholly unrelated or detached. These seem to be the first scientific observations on sun-spots in America.

The next undertaking to engage our astronomer's attention was the study of the transit of Mercury over the sun, April 27, 1740. Winthrop was fully aware of the importance of transit observations, especially those of Venus, and therefore proposed to observe these rare phenomena with well-thought-out methods. This he observed with an instrument he already possessed.

The qualitative results are probably not greatly different from our present knowledge of such transits, but it is in the methods of arriving at these results that the vast improvements have been made. Without the modern clocks, chronographs and electric circuit breaks —also firmly mounted telescopes with all the accessories—it is to be wondered that Winthrop accomplished his task at all. His results were accepted by the Royal Society and published in full in the *Transactions*.[33] Winthrop was thanked by the Royal Society and asked to continue his communications, which immediately gave him high rank and finally led to his election as a fellow. He followed his first paper with observations of the second transit of Mercury on October 25, 1743, and again a third transit on November 9, 1769. The problems in these transits which interested Winthrop were: the exact determination of longitude between Cambridge and London, the equation of time, the position of Mercury's nodes,

[33] *Phil. Trans.*, R. S., 42: 572–578, 1743.

its inclination and hourly motion, and the correctness of Newton's laws of motion.

Winthrop also established the first laboratory of experimental physics in this country in order to test the laws of gravitation of bodies on the earth. In conjunction with these experiments, he demonstrated to his students the motions of planets and comets, and illustrated the problems of eclipses, etc. Of course these lecture experiments had to do also with problems of the elements of mechanics, hydrostatics, optics, heat and the theory of light and prisms according to Newton. These experimental lectures which were given by Winthrop himself before the class were conducted much as are those in a modern laboratory—except that to-day the students perform the work themselves. The experiments were extended over a long period, beginning in 1746 and continuing to 1779. It is interesting to note that his manuscript notes are still preserved at Harvard College. It was during 1771 that Count Rumford, as a student at Harvard, attended Winthrop's lectures and thus derived his first knowledge of heat and other properties of matter. He said, "I made sufficient progress in Natural Philosophy under this excellent and happy teacher."

It has recently come to light that the first introduction into our colleges of the elements of fluxions now known as calculus was in connection with the thesis required of the students under Winthrop, beginning about 1756. This marks a definite epoch in mathematical studies which has interested students of history for some time.

The year 1755 was a memorable one to the inhabitants of New England, due to the occurrence of an earthquake of some severity. The study of this phenomenon called forth Winthrop's best endeavors and revealed at the same time a large and broad-minded scientist. As a theorist, he probably was more modern than he has been given credit for. His observations, deductions and the theory he advanced, besides the theological implications, were given in two lectures in the Holden Chapel before the students and faculty. The whole treatise shows an exceptionally comprehensive study. It is also a curious intermixture of analytical chemistry, mineralogy, geology and astronomy. However, this study virtually established Winthrop as our first seismologist. He was the first in this country to apply true inductive methods to observations of the earth-movement, and to advance the theory that the disturbances of the earth-crust were in the form of waves, and transmitted a pendulum-like motion to buildings and objects on the surface. He was the first to apply computation to the phenomena, consequently discovering the analogy between seismic motion and musical vibrations; he also discovered the principle that the quicker the motion the shorter the wave-length of the disturbance. His ideas on the nature of heat were new to the science of geology, especially those relating to the internal actions of volcanoes and earth movements. An account of this earthquake was also published in the *Philosophical Transactions*.[34]

Winthrop's next public work was two lectures upon comets, and in particular on the return of the comet (1682) better known as Halley's comet, which he was fortunate to observe, since it was the first predicted return of a comet. This lecture was also read in the chapel of Harvard College, April 11, 1759, as a part of the regular and assigned duty of the Hollis professorship. Winthrop first observed this comet on April 3, after it had passed perihelion, and, like similar celestial phenomena, had caused

[34] *Ibid.*, 50: 1–18, 1757.

much anxiety and speculation as to its meaning.

In the first lecture his introduction to the subject of comets is descriptive, showing the relation and differences between comets, fixed stars and planets. This is followed by a history of their discovery with various theories concerning their origin and nature, especially during the preceding two hundred years. He computed the orbital elements of one of the comets under observation during this period; and his work upon the geometrical demonstrations, suggested by Newton, concerning the ascent of the tails of comets, received laudable notices from the Royal Society. This paper, the original of which was in Latin, entitled "Cogitata de Cometis," was communicated to the society by Dr. Franklin.[35] It contains five problems, with dependent scholia and corollaries. In these he investigates the limits of attraction between the comets and the sun, and the laws of motion and direction by which an elastic fluid or vapor arising from the head of a comet would be governed. He also deduces the masses and densities of comets from the observed breadth of the coma in the side next to the sun. In this method, which he considers as entirely new to science, he infers that the density of the comet of 1665 was to the density of the earth as 350 to 1; and that of the comet of 1682 as 5 to 11; and suggests an analogy in this respect, between comets and planets; that the densities are greater in proportion to their nearness to the sun.

His explanation of the curved appearance of the tails of comets, which are occasionally manifested, contains this remark—"that as no incurvature or deviation from the opposition to the sun is perceived, but what may arise from the progressive motion of the head around the sun, it appears probably that comets do not revolve on their axes."

In his second discourse before the college community, April 18, 1759, he discussed the true theory of comets according to the work of Newton's "Principia," and also according to the laws formulated by Kepler, with the predictions of Halley.

Again we find him in 1761 preparing, with foresight and diligence, plans to observe two events of great astronomical importance which took place in this country—the transits of Venus, 1761 and 1769. Winthrop's keen sense of appreciation of the value of such opportunities was of vital significance in America's astronomical history. This is evident from the introduction to his first discourse in 1769 on the use of the transit of Venus.

The first astronomical expedition in this country was that in which Harvard College and the province of Massachusetts participated. That Harvard had a scholar so well trained, and disposed to undertake this scientific mission speaks well for her eminence in science at that period. The ultimate success of this work depended upon the cooperation of many astronomers. European observatories, Greenwich and Paris, sent out five different observing parties to America. In Philadelphia, the American Philosophical Society authorized David Rittenhouse and a number of prominent gentlemen to make all preparation to observe this transit also. A special act of the Massachusetts government granted the use of the province sloop to convey Winthrop and two assistants, with instruments loaned by the college, to St. John's, Newfoundland. Without giving full details of the time of contacts and measurements of the passage of Venus across the sun, it is sufficient to say that the results of the calculations gave the parallax of the sun as 8″.25. This value is apparently not

[35] *Ibid.*, 57: 132–154, 1767.

the mean value of the parallax as it was derived from one set of observations based upon Halley's method; namely, the "method of duration," that is, observation of the contacts, and also of the position of the planet on the sun. While Winthrop observed this transit very thoroughly and made careful computations, yet his instruments and methods were naturally not such as to give results to be compared with those of Newcomb and others from the transits of 1878 and 1882. However, he later gathered all available observations, and from these determinations found the sun's parallax, at its mean distance from the earth, to be 8″.68, which is comparable with the present accepted value. In the second transit of Venus (June 3, 1769), which again called forth important preparations both in Europe and the colonies, similar observations were made by Winthrop in Cambridge, by West in Providence, and by Rittenhouse in Philadelphia.

Winthrop was the main support of Franklin in his theories and conclusions relative to his experiments in electricity. With Franklin, he was virtually the founder of the study of atmospheric electricity. He also carried on magnetic and meteorological observations of which records and computations are still preserved. Parallel to his observations on earthquakes and magnetic variations, he observed regularly the appearance of the Northern Lights from 1741 to 1757. He also made a study of the physical appearance of Venus, eclipses of Jupiter's satellites, partial solar eclipses and aberration of light.

In all, Winthrop published his scientific results in six pamphlets and contributed eleven papers to the Royal Society.

There is another outstanding fact concerned with the history of our country's intellectual progress that is not generally known—namely, that the founding of the American Academy of Arts and Sciences can be attributed to Winthrop. With a strongly intellectual community now developing in Boston, our Winthrop found great need of further expression of scientific ideas. He was a close friend of John Adams and both of them were more or less jealous of the advances that Philadelphia was making in various ways. On several occasions both gentlemen discussed the possibility of founding an academy in Boston similar to the American Philosophical Society. Winthrop's health and manifold duties did not permit an active part in this undertaking, but you will note that all the best students who graduated under him are among the incorporators of the American Academy. During the trying times of the revolution with the mother country from 1775 to 1779, our scholar was an ardent patriot and espoused the cause of the colony. He was a councillor and friend of Washington and of others who stood high in the founding of the new republic.

Winthrop was honored as no man of his time had been. He was easily recognized as the most learned and capable of men during a period of over forty years of service to Harvard College. The Royal Society elected him as a fellow in 1766 and the American Philosophical Society enrolled him as a member in 1768. From the University of Edinburgh he received the honorary degree of LL.D. and his alma mater conferred the same degree upon him in 1773—the first honorary degree of doctor of law conferred by Harvard University.

In Cambridge, on May 3, 1779, at the age of sixty-five, John Winthrop, scholar, scientist and astronomer, passed away in the fulness of his fame. He lies buried with his ancestors in the old King's Chapel burying ground, Boston.

John Morgan, founder of the first medical school in America, was born in Philadelphia, 1735, and attended the College of Philadelphia, where he received his first degree in 1757. Young Morgan followed the old custom of serving as an apprentice to a well-known physician, and later became the resident apothecary to the Pennsylvania hospital, and from there saw service as an army surgeon. Thus he laid the foundation of a notable medical career which he enjoyed until the end of his life. In 1760 we find him studying in London under the famous Hunter brothers, and later in the well-known Medical School in Edinburgh, from which many of our colonial doctors graduated. He received his M.D. degree in 1763 from Edinburgh after presenting a thesis entitled "De Puopoiesis" in which he advanced the first ideas that pus was a secretion formed by the blood vessels when in a state of inflammation.

Morgan continued his medical studies, especially in anatomy, in the medical school of Paris. Here he had the great honor of reading two papers before the Royal Academy of Surgery, the first of which was entitled "Suppuration," and the second "On the Art of Making Anatomical Preparations by Corrosion." These lectures merited him the honor of election to that society. Morgan traveled extensively in Italy, France and England, and before sailing for home was elected a fellow of the Royal Society in March, 1765, in spite of the fact that he made no scientific contributions to the society's *Transactions*. He was also a licentiate of the Royal College of Physicians and the College of Physicians of Edinburgh.

The young colonial physician, fresh from study and travel, having met the best medical scholars of Europe and having received the highest honors in recognition of his ability, returned home ready to be of inestimable service to his country. He seems to have made special effort to prepare himself for the career of a medical teacher, as he took immediate steps for the establishment of a medical school at the College of Philadelphia according to the best ideas prevalent at that time. The project met with the immediate approval of the board of trustees, and on May 3, 1765, they elected him professor of the theory and practice of medicine, and on May 30th of the same year he delivered his famous inaugural address entitled: "Discourse upon the Institution of the Medical Schools of America." In this address Morgan laid down a very comprehensive plan for the preparation and education of all students of medicine, which plan has, in the main, been upheld by all our modern medical schools connected with universities. The first two professorships established were in anatomy and materia medica. Dr. William Shippen, Jr., a fellow student of Morgan while he was in Europe, gave the lectures on anatomy and surgery, which consisted of the structure of all parts of the body, and the various diseases affecting them, as also their various cures. All the necessary operations in surgery were performed, and courses in bandaging and the practice of midwifery were given.

Dr. Morgan lectured on materia medica, which consisted of the study of medicine in general and the proper manner of conducting the study of physic. He also took up the study of the virtues of different plants and their comparative powers of curing. His lectures upon pharmaceutic chemistry were open to students of both chemistry and pharmacy, and included some critical lectures upon the chief preparations contained in the "Dispensatories" of the Royal College at London and Edinburgh.

In October, 1775, General Washington appointed Dr. Morgan medical di-

rector of the Continental Army. Morgan set to work to bring order out of the chaos which existed in the Army Medical Department and instituted rigid examinations for those desiring to enter the medical service, and also exercised the most vigilant supervision over the work of the entire department. The jealousy and insubordination of the regimental surgeons contributed to his dismissal from his post of director general. As a result of this affair Morgan issued a pamphlet entitled "A Vindication of His Public Career in the Station of Director-General of the Military Hospitals and Physician-in-Chief to the American Army." Boston, 1777. Morgan's demand for vindication was finally heeded by Congress, and a formal investigation of the charges two years later proved Morgan innocent.

Morgan contributed three papers to the *Transactions* of the American Philosophical Society, of which the following are brief abstracts.

The art of Making Anatomical Preparations.[36]

A discussion on the method of preparing models of the vascular system of anatomical specimens as first used by Dr. Nichols in London and later introduced by the author in Paris, in which the advantage of its features over the older and more cumbersome method of dissection are pointed out so as to prompt its use by students in this country.

Of a Living Snake.[37]

Statement of the case of a living horse, 9 years old, with a live snake in its eye, given as supportive evidence for the theory of spontaneous generation. Several other cases of worms and snakes found in abnormal places are also mentioned. (The author does not seem to be a strict adherent to the theory, but rather is in doubt just which is correct.)

Some Account of a Motley Colored or Pye Negro Girl.[38]

Statements of the case of a negro girl with areas of white skin diffusely scattered over all portions of her body, and the case of the mulatto boy also showing areas of white skin contrasted with the slightly deeper natural hue.

Morgan possessed an ample fortune and he spent his latter years in collecting valuable works of art and accumulating a fine library. These were partly destroyed by British during the Revolutionary War. He died on October 15, 1789, and both he and his wife are buried in St. Peter's churchyard in Philadelphia.

John Tennent was a native of England and came to the United States about 1725. Little seems to be known about his early life and education, but he was apparently a man of unusual ability. He revisited England about ten years later, and upon his return to Virginia published what appears to be the first work on medicine printed in Virginia, namely "An Essay on the Pleurisy," printed by William Parks in Williamsburg in 1736. He also wrote a treatise on the diseases of Virginia and the neighboring colonies, but apparently this was never printed. He was an exponent of the virtues of Seneca (rattlesnake root) as a specific for many diseases. Tennent found that the Seneca Indians used rattlesnake root as a remedy for snake-bite, carrying it powdered in their shot bags for immediate use. He administered it to patients ill with pleurisy, pneumonia, gout and intermittent fever. In the year 1738 and again in 1742, in Williamsburg, he published "An Epistle to Dr. Richard Mead Concerning the Epidemical Diseases of Virginia, Particularly a Pleurisy and Peripneumony wherein is Shown the Surprising Efficacy of the Seneca Rattlesnake Root . . . Demonstrating the Highest Probability That This Root Will Be of More Extensive Use Than Any Medicine in the Whole Materia Medica." In another publication he gives an account of the seasonal diseases of Virginia, describing its marshes, creeks and rivers and the state of the

[36] *Trans.* Amer. Phil. Soc., 2: 366–383, 1786.
[37] *Ibid.*, 383–391.
[38] *Ibid.*, 392–395.

air calculated "to bring on a relaxation of the solids and consequently a viscidity of the blood." It must be remembered that his method of determining fever was by conjecture, as the thermometer was unknown for medical use.

It is recorded that he was elected a fellow of the Royal Society in 1765, and also that he possessed the degree of doctor of medicine. Apparently he made no contribution to the *Transactions* of the Royal Society.

Tennent's life in his later years seems to be as obscure as his early career. He apparently was an itinerant doctor of the colony of Virginia. Where he lived and died seems not to be known.

Alexander Garden was born in Charleston, South Carolina, in 1728, and received his medical education under the supervision of the celebrated Dr. John Gregory in Edinburgh and Aberdeen universities. He returned to Charleston in 1752, and established himself in the practice of medicine. During his residence in Charleston he became greatly interested in the flora of the colony, and with his excellent training as a scientist he was able to bring to bear a profound understanding of the important relation of plants to human welfare. In 1754, due to ill health, he was compelled to take a sea voyage, and upon his arrival in New York he was offered a professorship at King's College (now Columbia University), but it is reputed that he declined the honor. He returned to Charleston, where he amassed a fortune, being greatly esteemed and extensively employed. Although he possessed a profound knowledge of mathematics, philosophy and the science of his day, it was in botany that he made his greatest contribution to colonial science. To extend his knowledge of natural history he accompanied, in 1755, the governor of South Carolina, on an expedition to the Indian country and the mountains. On this expedition he discovered a rare earth equal to that used for Worcester china, but history does not record what became of the discovery.

Garden also made studies in zoology, especially fishes and reptiles, and kept up an active correspondence with Linnaeus, to whom he sent large collections of fishes. He also sent to Linnaeus, in 1770, a specimen of the Indian Pink Root, an account of which appears in the *Essays and Observations* of the Edinburgh Philosophical Society, Vol. 2, pp. 1–7, 1756. Linnaeus's admiration for Garden and his work prompted him to give the name "Gardenia" to an "entirely new and very singular genus, the Catti Marus of Rumphius, Amboin."

Garden was the discoverer of the Congo snake,[39] and was instrumental in sending the first electrical eels to Europe. He writes to Ellis, then secretary of the Royal Society, that he had not been able to examine the reptiles thoroughly, but the structure seemed so uncommon that he thought the specimens should go to the society immediately. Regarding the description of the Congo snake, he says that these fish (eels) are from two to three feet long with the power of shortening themselves several inches. They are about ten to fourteen inches in circumference about the thickest part of the body. The head is large, broad, flat, smooth and impressed here and there with holes, as if perforated with blunt needles. The eyes are small, flat and of bluish color, and placed about three quarters of an inch back from the nostrils, and more towards the sides of the head. He goes into some detail concerning the astonishing power they have of giving a sudden and violent electrical shock to any person or number of persons joining hands and having contact with the fish. When the eel is first caught it is capable of giving a very powerful shock.

[39] *Phil. Trans.*, R. S., 65: 102–110, 1775.

Among the papers which Garden sent to Ellis, and which were read before the society, but never published in the *Transactions*, were the following:

The Halesia first described by doctor Garden, as appears by the letter of T. Ellis, esq. F.R.S. read before the Royal Society, November 20, 1760.

An account of the male and female cochineal insects. In a letter to John Ellis, esq. read before the Royal Society, December 23, 1762.

An account of an emphibious bipes, (the mud inguana, or syren of South-Carolina) communicated in a letter to John Ellis, esq. read before the Royal Society.

An account of two new tortoises communicated in a letter to John Ellis, esq. read before the Royal Society, February 23, 1775.

Garden was honored by being elected a fellow of the Royal Society in 1773, and eventually became its vice-president. In 1783 his declining health prompted him to visit England and Scotland in the hope of arresting the disease which attacked him, but he passed away peacefully in London in 1792.

James Bowdoin was born in Boston, August 7, 1726, of wealthy and influential parents. He graduated from Harvard College (1745), and at an early age of 24 came under the influence of John Winthrop and Benjamin Franklin. Bowdoin early exhibited strong scientific inclinations instead of pursuing the mercantile career which had been designed for him. This taste for scientific pursuit induced Franklin, then twenty years his senior, to communicate to him his paper on electricity. This was the beginning of a long correspondence, both scientific and political, by which these friends became united in reputation. At the very beginning of this correspondence Bowdoin appears to have availed himself of Franklin's invitation to make observations on the theory and speculation of electricity with somewhat more independence of opinion than might have been expected from the disparity of ages. One of Bowdoin's earliest letters to Franklin suggested a forcible objection to the hypothesis that the sea was the grand source of electricity, which caused Franklin a year later to withdraw his suggestions on this subject. This same letter of Bowdoin's contained an elaborate explanation of the cause of the crooked direction of lightning, which Franklin pronounced both ingenious and solid, adding "when we can account as satisfactorily for the electrification of clouds, I think that branch of natural philosophy will be nearly complete." Many of these letters which passed between Franklin and Bowdoin were read before the Royal Society, and at a later date were published in a collected form.[40]

Bowdoin's later scientific works were published in three papers, which consisted in the main of a philosophical discussion of the subject of the new theory of light as advanced by Newton. The Newtonian theory of light was known as the emission or corpuscular theory of light in opposition to the undulatory or wave theory as advanced by Huygens much earlier and which Franklin had accepted. In these papers Bowdoin, in the main, refuted the arguments of Franklin. Since the beginning of the struggle of the adherents of these theories much theoretical and experimental work has been done, and to-day each theory has shown that it possesses facts of great value and upon which the quantum theory depends.

Bowdoin begins the controversy by quoting Franklin's arguments[41] as follows:

With respect to the hypothesis, it is asked—"May not all the phenomena of light be more conveniently solved, by supposing universal space filled with a subtle elastic fluid, which, when at rest, is not visible, but whose vibra-

[40] Franklin, "Experiments and Observations on Electricity," London, 1751.

[41] *Memoirs*, Am. Acad. Arts and Sci., 1: 188–189, 1785.

tions affect that fine sense in the eye, as those of air do the grosser organs of the ear? We do not, in the case of sound, imagine that any sonorous particles are thrown off from a bell, for instance, and fly in straight lines to the ear: why must we believe that luminous particles leave the sun, and proceed to the eye? Some diamonds, if rubbed, shine in the dark, without losing any part of their matter. I can make an electrical spark as big as the flame of a candle, much brighter, and therefore visible further; yet this is without fuel: and I am persuaded no part of the electric fluid flies off in such case to distant places, but all goes directly, and is to be found in the place to which I destine it.—May not different degrees of the vibration of the abovementioned universal medium, occasion the appearances of different colours? I think the electric fluid is always the same; yet I find that weaker and stronger sparks differ in apparent colour: Some white, blue, purple, red;—the strongest, white; weak ones, red."

From this Bowdoin lays down his thesis in three interesting statements of which the first is as follows:[42]

I. "Observations upon an Hypothesis for solving the Phenomena of Light: with incidental Observations, tending to shew the Heterogeneousness of Light, and of the electric Fluid, by their Intermixture, or Union with each other."

By Franklin's hypothesis, Bowdoin reasons that if universal space be a vacuum and filled with subtle elastic fluid which is at rest, accordingly there will be complete darkness. Should, however, any part of the fluid (now known as ether) be in motion, due to vibration, and consequently the whole, we would have universal light, which in either case is not possible. Bowdoin reasons again that, even if light and sound waves were similar, then according to the theory of universal fluid light would surround objects just as sound does, but this can not be the case from the evidence shown by objects casting shadows.

In Bowdoin's second paper,[43] was: "Observations on Light, and the Waste of Matter in the Sun and fixt Stars, occasioned by the constant Efflux of Light from them: with a Conjecture, proposed by Way of Query, and suggesting a Mean, by which their several Systems might be preserved from the Disorder and final Ruin, to which they seem liable by that Waste of Matter, and by the Law of Gravitation."

In this paper Bowdoin proceeds to show the fallacy of Franklin's argument that according to the Newtonian theory the particles of matter called light being continually driven off from the sun's surface as well as the planets and comets would have a tremendous motion and a force exceeding that of a 24-pounder discharged from a cannon. Also that the sun and planets must be exceedingly diminished by such a waste of matter. He reasons that "If, then, we can suppose the quantity of matter in a particle of light to be, not indeed absolutely, but comparatively, 0, its momentum will also be comparatively 0; and it can have, in that case, no visible effect on the smallest particle of dust to remove it."[44]

The third memoir[45] sums up all Bowdoin's philosophical speculation of the universe and his comprehension of Newton's law of gravitation. It is the longest of his memoirs and apparently his final effort to advance creative philosophical thought in the colonies. He offers it in the form of "Observations tending to prove, by Phenomena and Scripture, the Existence of an Orb, which surrounds the whole visible material System; and which may be necessary to preserve it from the Ruin, to which, without such a Counterbalance, it seems liable by that universal Principle of Matter, Gravitation." In this paper he argues the various hypotheses concerning the nature of the Milky Way

[42] *Ibid.*, 1: 187, 1785.
[43] *Ibid.*, 1: 195–207, 1785.
[44] *Ibid.*, 197, 1785.
[45] *Ibid.*, 208–233, 1785.

and nebulae, and the universal aspect of Newton's law of gravitation. The paper is also characteristic of scholars of the day, in that his scientific deductions are full of theological inferences.

Bowdoin's life was very similar to that of Franklin's in that they both played leading parts in the political life of their community and were strongly in favor of united colonies. Likewise, both longed for scholastic retirements. Bowdoin became governor of the Commonwealth of Massachusetts and distinguished himself by his firmness and integrity. He was also a counsellor of both Washington and Adams, and a fellow of Harvard College, one of the founders and the first president of the American Academy of Arts and Sciences of Boston, 1780. He was honored by his alma mater and the Edinburgh University with the honorary degree of LL.D. and was elected fellow of the Royal Society in 1788. The lives of Franklin and Bowdoin ran parallel even until the end, for he followed Franklin to the grave within a few months, dying on the 6th of November, 1790, and was buried in the Granary burying ground in Boston.

No more interesting or remarkable creative genius has thus far been revealed in our history than that which was embodied in David Rittenhouse.[46] A son of the soil, he was a self-made astronomer, a true product of American genius and toil and the highest embodiment of the pioneer spirit in science during the colonial period. He was born on April 8, 1732, the year of Washington's birth, near Germantown, Pennsylvania. His father abandoned paper-making, which was established in this country by his ancestors in 1690, and moved to a farm in Norriton, about twenty miles from Philadelphia. David, the oldest son, third child in a family of ten, at an early age was destined for farm work. His mechanical ability attracted attention by his boyhood productions, including a miniature waterwheel. This talent received encouragement at twelve, when he inherited a chest of carpenter's tools and mathematical books from his maternal uncle. No schooling beyond the three R's was available, but he assimilated all the books he could procure showing special fondness for mathematics and astronomy and covering plow-handles, fences, stones and barn doors with figures and constellations. At seventeen he made a wooden clock, followed by a metallic timekeeper. His father reluctantly let him quit the plow, and at nineteen he opened a shop on the farm for clock-making, where he worked and studied assiduously, seriously impairing his health. At this time he is said to have mastered Newton's "Principia" in the English translation of Mr. Mott; and with his native ability, he laid the broad foundation for his future astronomical work. Among his great mechanical contributions to the history of instrument-making in this country was his construction of a transit instrument, the first made in America. This is still preserved in the venerable American Philosophical Society in Philadelphia. Aside from constructing a number of astronomical clocks, of which one is also preserved in the rooms of the above society, he made the first orrery in America in 1767.[47] One, the first, was made for the College of New Jersey and the second for the University of Pennsylvania, which is still to be seen there. The technical skill and the profound knowledge of astronomy was most essential in carrying out these mechanical devices.

Rittenhouse's first astronomical work was the complete study of the transit of Venus,[48] which included the work of

[46] Portion of this sketch was furnished by Dr. W. Carl Rufus.

[47] *Trans.*, Am. Phil. Soc., 1: 1–3, 1789.

[48] *Ibid.*, 1: 4, 8–38, 1789.

others. A projection of this transit was laid before the American Philosophical Society. The society appointed three committees and selected three observing sites. The first was State House or Independence Square in Philadelphia, the second on the farm of Rittenhouse some twenty miles northwest of Philadelphia, and the third near Cape Henlopen. Each of these were in the charge of prominent scholars of the community. The society lacked funds, and instruments were expensive. Politics helped to equip the State House station. It was "provided with an excellent sector of 6 feet radius, made by the accurate Mr. Bird, and an equal altitude and transit instrument, both belonging to the honourable Proprietaries of this province, which the Governor very generously lent to the society on this occasion." Telescopes and additional equipment for the State House Square were obtained from England. The farm did not fare as well. A Gregorian reflector with a Dolland micrometer was ordered from London to be used by Dr. Smith. With it came lenses for a refracting telescope for Harvard. Arriving too late to be forwarded before the great event, they were impressed into service, fitted together by Rittenhouse and used by Mr. Lukens.

Rittenhouse was left to his own resources. In preparation he made an equal altitude instrument, a transit telescope and an excellent timepiece, upon which depended the accuracy of the observations. He spent several months determining the latitude and longitude of the observatory, rating the clocks and making preliminary computations.

The success of the observations was due to Rittenhouse. Maskelyne, the astronomer royal of England, acknowledging their receipt from the Honorable Thomas Penn, governor of the province, says, "I thank you for the account of the Pennsylvania observations, which seem excellent and complete, and do honor to the gentlemen who made them." Rittenhouse immediately began the reductions. Data by the Norriton station combined with Greenwich observations gave the most accurate value of the sun's distance, 92,940,000 miles, in striking agreement with the present adopted value, 92,900,000 miles.

Rittenhouse also observed an atmosphere of Venus, a phenomenon which escaped the astronomer royal. Other astronomical activity of Rittenhouse during this period included a transit of Mercury, November 9, 1769, a survey between the observatories of Norriton and Philadelphia, observations of Lexell's comet, 1770, and the determination of its orbit, "the fruit of three or four days labor." A paper on "An Easy Method of Deducing the Time of the Sun's Passing the Meridian" attracted the favorable attention of VonZach.

Early in November in 1768 Rittenhouse[49] began building the Norriton Observatory, the first astronomical observatory in the colony. This was to be equipped with the above-mentioned instruments, but due to labor trouble and weather conditions, and possibly the "ill state" of his health, apparently the observatory was never completed, and had his project been fully realized no doubt this observatory would have paralleled any in Europe at that date. However, despite its incompleted state, Rittenhouse accomplished his great objective, namely, to observe the transit of Venus.

Rittenhouse contributed nineteen papers in all to the *Transactions* of the American Philosophical Society, and therefore it is not possible, within the limits of this paper to review them all. It is, however, important to call attention to our self-disciplined scholar's great aptitude to higher mathematics, in which field he attained some degree of

[49] *Ibid.*, 1: 8–13, 1789.

BENJAMIN FRANKLIN

FROM AN OLD ENGRAVING BY FISHER FROM THE MASON CHAMBERLIN PORTRAIT.

success. Rittenhouse writes, in May, 1792, to his friend Robert Patterson, professor of mathematics at the College of Pennsylvania, "to discover if any one has been able to determine a method of finding the sum of the several powers of the sines, either to a radius of unity or any other."[50] His problem is:

> The sums of the odd powers of the sines bear a very simple relation to each other, and so do the sums of the even powers. But all the sums of the odd powers are incommensurable to all those of the even powers.

[50] *Ibid.*, 3: 155–156, 1793.

> If we take the radius equal to unity, the sum of all the sines, or their first powers, will be = 1, and the sum of all their squares = 1/2 multiplied by the arch of 90°. The sum of all their cubes is = 2/3, and the sum of their fourth powers = 3/8, multiplied by the arch of 90°. The sum of the fifth powers is = 8/15, and the sum of the 6th powers = 5/16 multiplied by the arch of 90°.

Rittenhouse was able to demonstrate the first two cases by ordinary arithmetical means, but the others were investigated by the method of infinite series. The subject of infinite series was just being revived by the leading

DR. JOHN MORGAN

REPRODUCED FROM MORRIS'S "EARLY HISTORY OF MEDICINE IN PHILADELPHIA."

scholars of Europe and to Rittenhouse credit must be given for keeping abreast of his time. His next paper,[51] of interest in the history of mathematics in the United States was a "Method of raising the common Logarithm to any number immediately." Here he demonstrated by laborious calculations the results which we to-day attain within a few minutes by the use of the modern slide rule.

[51] *Ibid.*, 4: 69–71, 1799.

The third mathematical paper[52] of Rittenhouse is upon the use of converging series to determine the true place of a planet in an elliptical orbit directly from the mean anomaly. For simplicity of method there is little to be desired in his manner of attacking the problem. This paper further reveals his venture into the realm of higher mathematics, especially into celestial mechanics without the use of modern calcu-

[52] *Ibid.*, 4: 21–26, 1799.

his. From a study of these three particular problems and his method of analysis it is evident that Rittenhouse arrived at some notion of fluxion which he is reputed to have discovered for himself independently of Newton.

On February 24, 1775, Rittenhouse delivered an historical oration[53] before the American Philosophical Society, in which address he considered the whole of the history of astronomy, pointed out some of the impending problems and the cultural effect upon the human mind. Like his senior contemporary, John Winthrop, at Harvard College, he showed great breadth of mind in that he had a full grasp of the history and problems of natural philosophy, including astronomy. Likewise, the great veneration and admiration of these two men for the life and works of Sir Isaac Newton was of a common order, and demonstrated their keenness to keep in touch with the great European scientists.

The subject of the theory of light, magnetism and electricity, and allied problems, was constantly before Rittenhouse, and led to frequent discussions with Benjamin Franklin and many other local contemporaries. It is interesting to note that from the absence of correspondence it is apparent that Rittenhouse corresponded in a scientific way with no one outside of Philadelphia.

Rittenhouse enjoyed the immediate friendship of Washington, Jefferson and many others prominent in colonial public affairs. Washington appointed him the first director of the United States Mint, and upon the death of Franklin in 1790, he became the second president of the American Philosophical Society. In spite of his struggle against ill health and financial worries, his life was that of a pure idealist. This motive, combined with the will to do, carried him to the highest office any scholar could desire. Although he made no contributions to the *Transactions* of the Royal Society, Rittenhouse was elected a fellow in 1795 (the last to be elected fellow during the eighteenth century). He received honorary degrees from Harvard, Princeton and Pennsylvania colleges. He died on June 26, 1796, while still president of the American Philosophical Society, and lies buried in the Presbyterian churchyard in Philadelphia.

[53] Barton, "Memoires, on the Life of David Rittenhouse," Philadelphia, 1813.

Conclusion

We have attempted in the foregoing pages to review in a very brief manner the most important contributions of the colonial scholars to the pioneer movement in the history of scientific thought in this country, as well as the extent of the Royal Society's influence during the first 150 years. Unfortunately we could not take into consideration the work of others equally important, due to the limitations imposed upon this paper, namely, that only fellows known and reputed to have been elected to the Royal Society were to be considered. It seems rather incomprehensible that the names of John Clayton (1693–1773), of Virginia, in botany; John Bartram (1699–1777), of Philadelphia, in botany; Cadwallader Colden (1688–1776), of New York, in electricity and gravitation; and Thomas Robie (1689–1729), of Harvard College, in astronomy and mathematics, besides various well-known tutors of Harvard and Yale Colleges, did not appear on the records of the Royal Society as fellows. This strange omission, however, does not in any way detract from their importance as scientists, and their work will be considered when a fuller history of colonial science is written. We also regret that it is not possible to consider the works of Benjamin Thompson (Count Rumford), elected fellow in 1779 and Joseph Priestley, fellow, 1776,

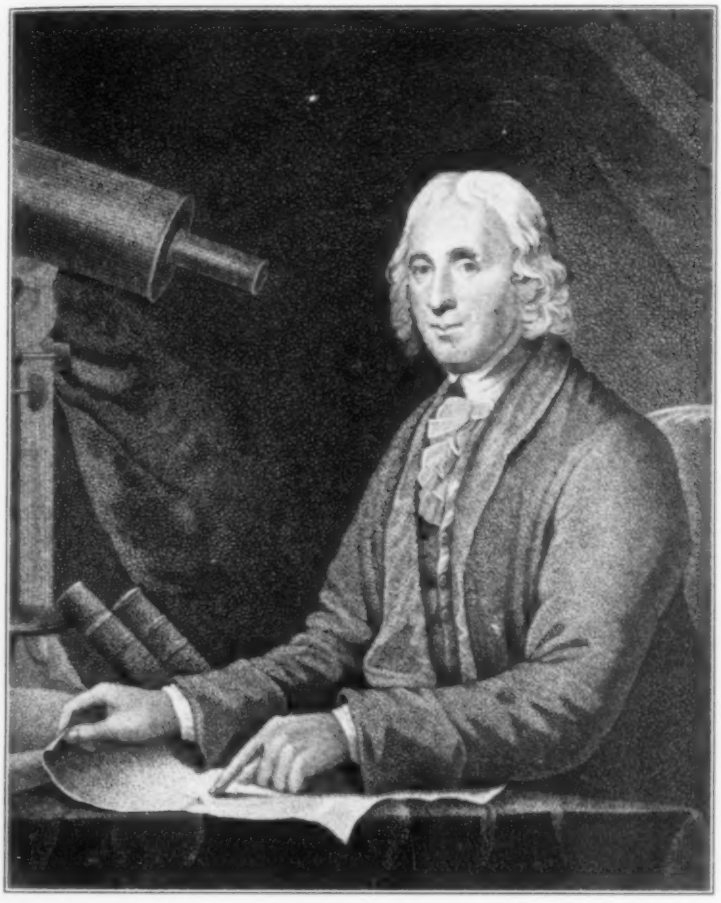
JOHN WINTHROP

ENGRAVED FOR THE COLONIAL SOCIETY OF MASSACHUSETTS FROM A PORTRAIT BY COPLEY IN POSSESSION OF HARVARD UNIVERSITY.

as the interchange of their abode was such that each made their greatest contributions to science while not residents of the colonies.

In closing this brief survey of the transition and progress of scientific thought from the mother country to the colonies, we have attempted to show how it was dominated in part by Puritanism, natural theology and supernaturalism, which held sway until the close of the Revolutionary War, when the English school of philosophy of rationalism and empiricism in matters of science was fully attained.

The transition of civilization as carried on by the French, Spanish and Dutch during the colonization period of America in the seventeenth century seems not to have touched the British colony. This may be accounted for in the constant warfare for supremacy, or possibly because their cultural and material influence was too foreign for the



C. W. Peale, pinxit *C. Galbrecht, sculptor*

DAVID RITTENHOUSE, LL.D., F.R.S.
PRESIDENT OF THE AMERICAN PHILOSOPHICAL SOCIETY.

Puritan colonials. However, with the signing of the Treaty of Paris in 1783 there appeared a new cultural movement when French scientific thought began to play a part in the history of scientific progress in the new republic, which movement covered a period of nearly fifty years, and this in turn was followed by a Germanic influence. The history of these latter movements will form a second chapter in the history of science in the United States.

David Starr Jordan

THE PROGRESS OF SCIENCE

DAVID STARR JORDAN

By a fortunate chance the forces back of heredity combined to endow David Starr Jordan with a great vigorous body, an eager mind with a poetical turn, and a rare capacity to note and remember form, size and color. Men like to use their strongest powers. It was natural that a man with a love of nature who could remember every detail of structure without visible effort should be a morphological zoologist, and just as natural that when his attention was turned to fishes that he should become the outstanding systematic ichthyologist of his time. Fish are ubiquitous and of infinite variety. The free course of stream, lake and ocean give them wide range. Following them over the world was the great sport of Dr. Jordan. It led him to know many countries and men of all nations and to be a true citizen of the world. Kind, idealistic and sympathetic, the woes of others became his woes. From boyhood he had recoiled from brutality and from that highest of brutalities that is called war. As he learned more of the world and its history, war became to him the one major disease of society. To hold it in check, to fight its ravages, to work for its eradication, became his master passion. Trained as a scientist, gifted as a simple, effective, convincing speaker and author, motivated by deep feeling and conviction, he began to use his facile epigrams, his poetic powers, his writing instinct and the facts gathered by a driving personal industry to marshal the forces of peace. His ease in friendship, his willingness to travel, his capacity not to see obstacles, made him a world figure in the struggle for the

SERRA HOUSE

THE ENTRANCE TO THE JORDAN RESIDENCE ON THE CAMPUS OF STANFORD UNIVERSITY.

THE GARDEN BEHIND THE JORDAN HOME

WHERE DR. JORDAN SPENT MUCH OF THE TIME IN THE LAST YEARS OF HIS LIFE.

pacific settlement of international disputes.

It was as a teacher and university administrator that Dr. Jordan built his own memorial. Senator and Mrs. Stanford had the funds, and the general plan of founding a university, but Dr. Jordan gave Stanford University its life and purpose. Keen in his judgment of men, tolerant of the ideas of others, daring in experiment, he struck out for the best in men and in ideas and pioneered the young institution through prosperity, financial collapse, earthquake and many deferred hopes.

New thoughts and new plans intrigued him, so that his best life's work was done in the moulding of a new university. His love of man, his leadership, his own wholesome life and character, made him a towering figure in education in California and the nation.

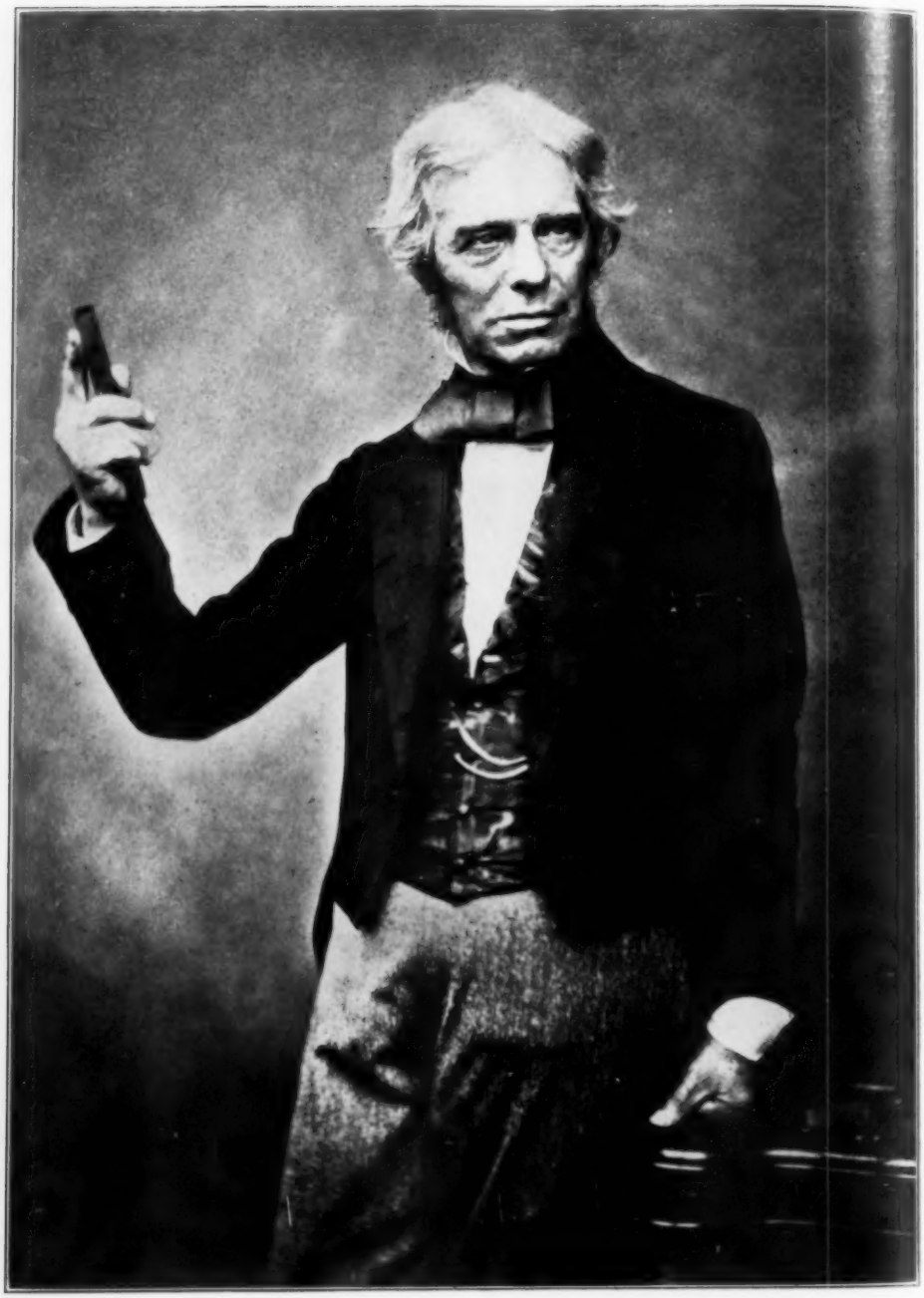
As scientist, internationalist and administrator, he thoroughly enjoyed life and gave inspiration to others. His unusual physical endowment carried him clear and unafraid into his eightieth year, when nature slowly brought him down, just as a great old oak falls in the forest. But he will live on and on in science, in literature and in the hearts of many thousands who loved him.

RAY LYMAN WILBUR

THE WORK OF FARADAY AND HENRY

FARADAY and Henry started the race toward immortality at scratch. One was New York Scotch and the other was plain English. Both had the advantage of starting poor and being self-supporting from early youth.

Faraday was eight when Henry was born. At thirteen he was apprenticed to a bookseller and bookbinder, where he remained for eight years. There he read Mrs. Marcet's "Conversations on Chemistry" and electricity in the "Encyclopaedia." One of the customers of the shop found him reading chemistry, and he was so greatly impressed by his conversation on that subject that he invited him to Sir Humphry Davy's last course of lectures at the Royal Institution. Faraday bound his notes together with illuminating illustrations and sent the copy to Davy, the director, begging him for an opportunity to quit trade, which he detested, and to take up science, which he loved. Not long thereafter, to his surprise, he obtained the coveted position as laboratory assistant. From 1813 to 1867 he both lived and worked at the Royal Institution. He married at thirty. The early years were taken up in routine and learning. In 1820 he published on two new compounds of iodine, carbon and hydrogen. The next year he made a wire carrying a current revolve around a magnetic pole. Then he became a pioneer in making alloys of steel. In 1823 he liquefied chlorine, and within the next three years he published on new compounds of carbon, and hydrogen and sulphonaphthalic acid. This work formed the basis of the dye industry. He swerved incessantly from chemistry into physics. In 1826 he was studying the limits of vaporization. From '25 to '29 he was on a committee to improve optical glass. In '29 he gave the Bakerian Lecture, "On the Manufacture of Glass for Optical Purposes." The glass was of little commercial value, but by doing the work he was enabled to get a valued assistant who remained with him for forty years. In 1831 he published papers on "A Peculiar class of Optical Deceptions" and on "Vibrating Surfaces." He was now forty years old and destined to begin and bring to quick fruition within the year the experiments on the production of electricity from magnetism. This is basic to the electrical industry. Quite properly the world joined with the Royal In-



MICHAEL FARADAY

stitution this September for centennial celebration.

Tyndall said Faraday's method of attack was intuitive rather than logical. Oersted (1820) had discovered that magnetism may be produced by electricity. Faraday inferred therefore that it should be possible to produce electricity from magnetism. Before we discuss his approach to this thesis, suppose we go back and see what has happened to his competitor in the meantime.

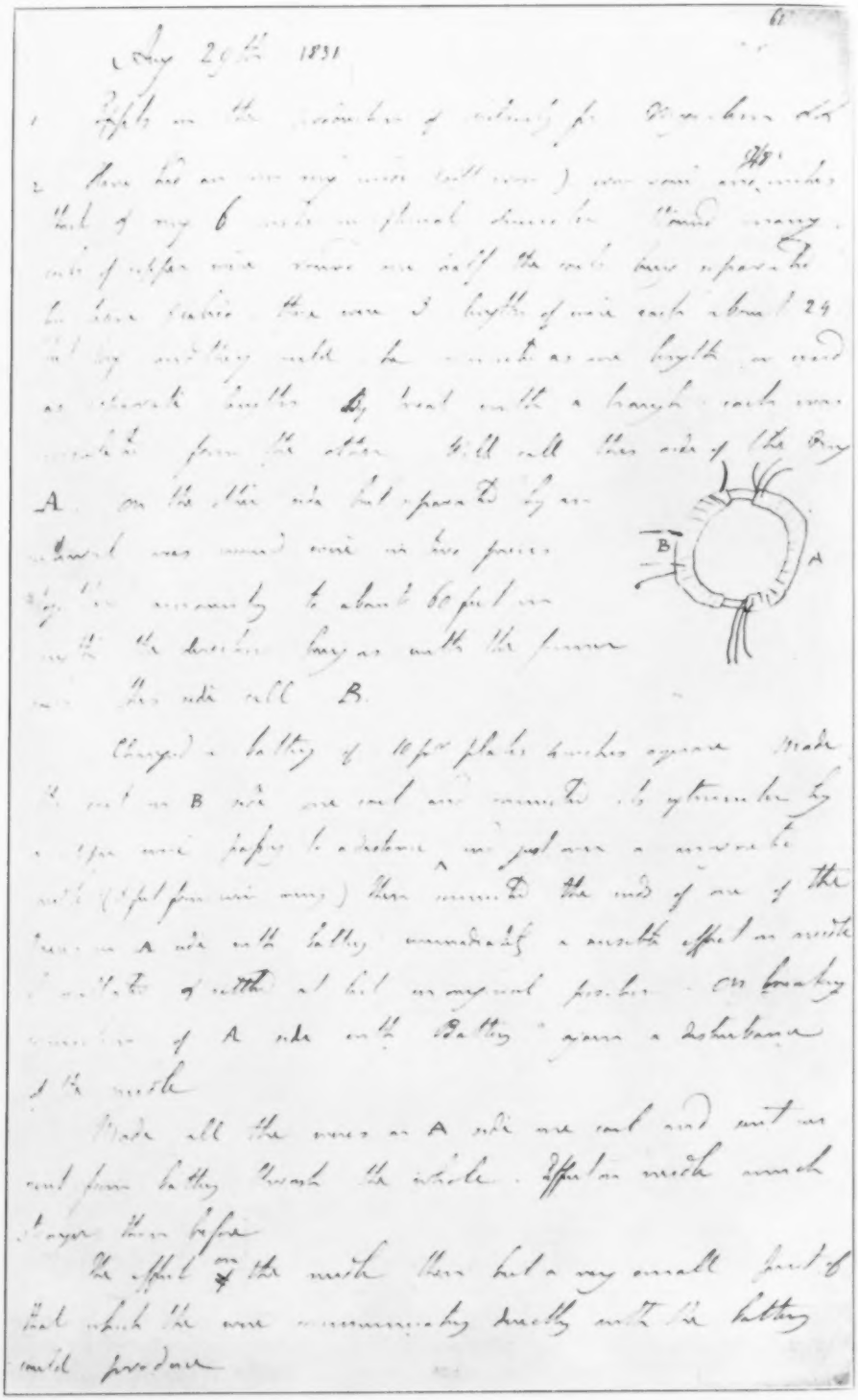
Joseph Henry had no more schooling than Faraday. His mind also was inquisitive, but he had less aptitude for study. His father died when he was nine and he was truly a child of fortune. Once he was chasing a pet rabbit through a foundation wall and discovered a back entrance to the bookshelves of the village library. There he found a book—"Brooks Fool of Quality." He returned several times to finish the book and finally read all the fiction available. Like Faraday he was an office boy in a store and later at fifteen he became an apprentice to a silversmith. There he learned to use his hands. When the store failed he had free time to gain a fondness for the theater. He joined a juvenile theater society, dramatized a tale, wrote a comedy, took part in the presentation and quickly became the president.

While ill at his mother's home he picked up a book left by a boarder. "Lectures on Experimental Philosophy, Astronomy and Chemistry intended chiefly for young persons. By G. Gregory." It is interesting that a chance book should have been the key to his career as it was with Faraday. On the fly leaf of this book he wrote, "This book although by no means a profound work has, under Providence, executed a remarkable influence on my life." "It accidentally fell into my hands—It opened up a new world of thought and enjoyment, invested things before almost unnoticed with the highest interest: fixed my mind on the study of nature, and caused me to resolve to immediately commence to devote my life to the acquisition of knowledge." As soon as he was able to attend the Theater Society he resigned from the presidency and announced that he would henceforth play his part on another stage.

He went to night school at the Albany (N. Y.) Academy and taught country school in the daytime. Later, he tutored the sons of General Van Rensselaer—and following this directed a road survey. Then at the age of twenty-seven he was made an assistant at the Albany Academy and in 1828 was promoted to professor of mathematics. It seems miraculous that such a young man, without education, experience or contact with any other research man, should do most profound research work immediately. Moreover, he lived in a community that had not deified science since the time of Franklin. He progressed more by that kind of thinking used by the Yankee inventor than by the use of lengthy logic. Yet he did not seem to have the least desire to invent for riches.

Sturgeon had made the first practical electromagnet by bending a piece of steel in U shape and winding 18 turns of copper wire around it. The steel was covered with insulator. Henry reasoned that more turns would make a stronger magnet. So he conceived the idea of covering the wire with silk insulation instead of insulating the iron core. This permitted 400 turns instead of 18. But it was hard work to put so many turns directly on a horseshoe magnet, so he devised the method of winding the wire on a "spool" or "bobbin" and then slipping the spools over the magnet. If the wheel is man's greatest mechanical invention then we must give a high place in the electrical field to the invention of the bobbin.

Henry in 1829 found that two of these bobbins or coils, connected to separate batteries, increased the lift of his magnet



A PAGE OF FARADAY'S DIARY

RECORDING THE DISCOVERY OF ELECTROMAGNETIC INDUCTION.

from 14 to 28 pounds, whereas if the two coils were connected end to end to the same battery the lift was not increased. On the other hand, he found that if the magnet was operated with a long external circuit the greater lifting force was obtained by placing the coils in series. Thus connected and with 1,060 feet of copper wire in external circuit, the magnet would support a half pound weight. He remarked that this looked as though the telegraph might be possible. He created this type of magnet, which he termed "Intensity Magnet." Also in 1831 he placed the coils in parallel where there was no external resistance and succeeded in lifting a 2,300 pound weight with an 82½ pound magnet. This was his quantity type magnet.

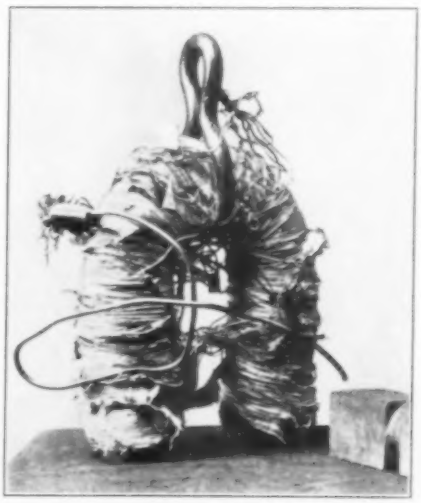
About the same time he made a demonstration of the telegraph. A mile of wire connected a battery and an intensity magnet. A narrow steel rod as a permanent magnet was pivoted to swing horizontally like a compass needle. One end was near the soft iron core of the magnet, and the opposite end was near a small stationary office bell. At each excitation of the electromagnet, the free end of the compass rod tapped the bell. The professor repeated this exhibit before his classes in 1831 and 1832, and he continued to make this demonstration after going to Princeton. Also he extended a circuit across the campus from his house to the laboratory, so that he might communicate relative to the serving of his meals. These illustrate his usual approach to knowledge.

In July, 1831, an account appears in *Silliman's Journal of Science* of the first electric motor. He wrote to the editor:

> I have lately succeeded in producing motion in a little machine by a power which I believe has never before been applied in mechanisms—by magnetic attraction and repulsion. Not much importance, however, is attached to the invention since the article in its present state can only be considered a philosophical toy; although in the progress of discovery and invention it is not impossible that the same principle or some modification of it on a more extended scale may hereafter be applied to some useful purpose. But without reference to its practical utility and only viewed as a new effect produced by one on the most ingenious agents of nature, you will not think it unworthy of a place in the *Journal of Science*.

In this motor a straight armature was wound with wires and pivoted above a horseshoe magnet. Either end down made contact with a separate battery so that there was continuous rocking motion. The modern motor disposes of the reciprocating motion by using the commutator.

Prior to September, 1831, Henry had made several experiments on the self-induction of an electric current. When a simple coil of insulated copper strip was disconnected from the battery circuit, he noted a fatter spark than when the coil was not interposed. He used the human body to measure the "projectile force" or "intensity" of this induced current. The body was a voltmeter. With low resistance circuits the galvanometer sufficed. When two closed coils were side by side, the stopping of the current in the first coil would induce



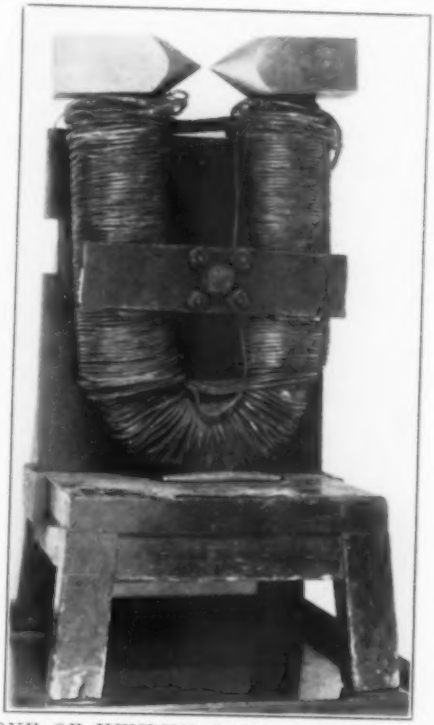
FARADAY'S "GREAT" ELECTROMAGNET

JOSEPH HENRY

a current in the second. This discovery of mutual inductance is the basis of much of our electrical machinery to-day. Henry further showed the principle of changing voltage and current as applied to transformers. It is now generally agreed that Henry was an independent discoverer of electromagnetic induction, but standard practice gives credit to Faraday for first publication (November, 1831). Moreover, Faraday sought and sensed the unity of all electric phenomena and presented a much clearer picture of the whole process. The naming of the unit of inductance for Henry and the unit of quantity for Faraday is probably equitable.

Faraday had contributed very little before he was forty, but for his achievement after August, 1831, Magie has said that the record of his life presents the largest and most important contribution ever made to science by an experimental physicist.

By rapid steps he proceeded to "convert magnetism into electricity," as designated in his notebook nine years previously. First he wound two separate coils on a wooden insulator, expecting to produce a steady current in the second coil by an unvarying current in the neighboring coil. But this did not happen. There was only a mere kick of the galvanometer at the instant of starting or stopping the battery current. If the coil with battery current were quickly approached to the other coil there was a current induced during the motion. On August 29[1] he welded the ends of an iron rod together so as to form a ring. Separate copper coils were wound on opposite sides of the ring. The coil on one side was connected to a galvanometer, and the other to a battery. There was now no doubt about the realness of the induced current at the instant of making or breaking the battery current. Clearly the current was induced only when the magnetic field was changing. He then tried a straight iron bar with two separate and distinct coils. If it were a changing magnetic field that produced the current, then he should be able to detect a current by thrusting a magnet into the closed coil. This proved correct. Next he obtained these effects on a larger scale, using a powerful permanent magnet. These experiments enabled him to explain the mysterious Arago disc experiment. Moreover, he was able to rotate the copper disc between the poles of the large horseshoe magnet and obtain a steady flow of current in a galvanometer connected between the axis and the rim of the disc. The current was reversed by reversing the direction of rotation. He then proceeded to outline explicit rules for mag-



ONE OF HENRY'S ELECTROMAGNETS

[1] Lord Rutherford states that Faraday's order of experimentation was with the ring first. (*London Times*, September 21, 1931.)

netic induction and first used the term "lines of magnetic induction."

Henry enjoyed a well-rounded lot of human experiences, but he was not generally chasing rabbits. The stage left the usual mark. He was obviously keenly interested in making and demonstrating the biggest magnet as well as in learning the technique. He would not have declined the prestige and honor of the Princeton professorship, even had his duties at Albany been purely research. As secretary of the Smithsonian Institution he probably had power and fame unequaled by any scientific man of his day. Almost by the time he was full grown, he had become instrumental in developing the two most important phases of our Machine Age, power and wire communication. Also he made a near approach to the discovery of radio waves when he magnetized a needle by placing it in a circuit distant from another circuit carrying an oscillating current. If Faraday may have been intuitive in his approach, one may ascribe to Henry the inspirational approach. As Sir William Bragg has said, Faraday was constantly seeking the simple unity of things. This applied not only to static, current and galvanic electricity, magnetism, light and matter, but also to gravitation. It is safe to say that if he had realized the relation between gravitation and electricity, it would have been expressed in a meaningful language.

The foregoing is merely an introduction to the lives of Michael Faraday and Joseph Henry, as a centennial greeting to the Royal Institution. It is not intended as a specific allocation on the scale of the immortals.

F. C. Brown